December 2011

# AEROSPACE AMERICA

# YEAR IN REVIEW 2011

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

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***December 2011***



## THE YEAR IN REVIEW



## BULLETIN



Cover: 2011 marked the last time the space shuttle would be seen streaking across the sky. Image courtesy NASA.


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# Editorial

## The future of biofuels grows brighter

In both military and civil aviation the tide is increasingly turning to alternative sources of energy. Considered an environmentalist's panacea with no practical value 10 years ago, these sustainable alternative fuels are now looking at a much more promising future.

The U.S. military has wholeheartedly embraced the use of biofuels: The Air Force has already approved a 50% biofuel blend in its F-15 and F-16 fighters and C-17 transports; it is seeking to certify all of its models by 2013 and hopes to get 50% of its total fuel from alternative, sustainable sources by 2016. The Navy has launched a project to invest up to half a billion dollars in biofuel refineries, and at a conference in Mississippi earlier this year, Navy Secretary Ray Mabus said the Navy hopes to be at 50% use of non-fossil-fuel energy by 2020.

Now the international airline industry is following suit. In July, ASTM International approved a 50% mixture of fuels derived from plant oils and animal fats and conventional kerosene for use in commercial flights. European airlines immediately began trial flights, with Lufthansa leading the way. Several other airlines swiftly followed suit. Then, in November, U.S. carriers United and Alaska Airlines began their own trials. All of the airlines reported seamless flights, with no complaints from operators or passengers.

These alternative fuels are derived from widely different sources—from exotic plants like Jatropha to used cooking grease to farmed algae—and have much to recommend them. They are drop-ins, that is, they can be blended with conventional jet fuel without any engine alterations; they result in slightly less fuel consumption, which may mean little in one aircraft on one flight but has significant impact fleetwide; and they generally have a slightly smaller carbon footprint. Plant fuels like camelina grow in fallow wheat fields, so they do not displace food crops, and algae farms can be developed almost anywhere.

However, these fuels also have significant drawbacks. They are still far more expensive to produce; some say five times higher, some say even more. There are fears that in some regions, particularly poorer countries, they may supplant food crops because they demand a higher price. And some airlines, at least for the short term, may find it cheaper to buy carbon credits than alternative fuels that may not have that much impact on their carbon footprint.

But as much of the Western economy seems to teeter daily on the edge of free fall, and chaos surrounds precisely those areas that are the source of much of the world's conventional jet fuel, it is good to have choices.

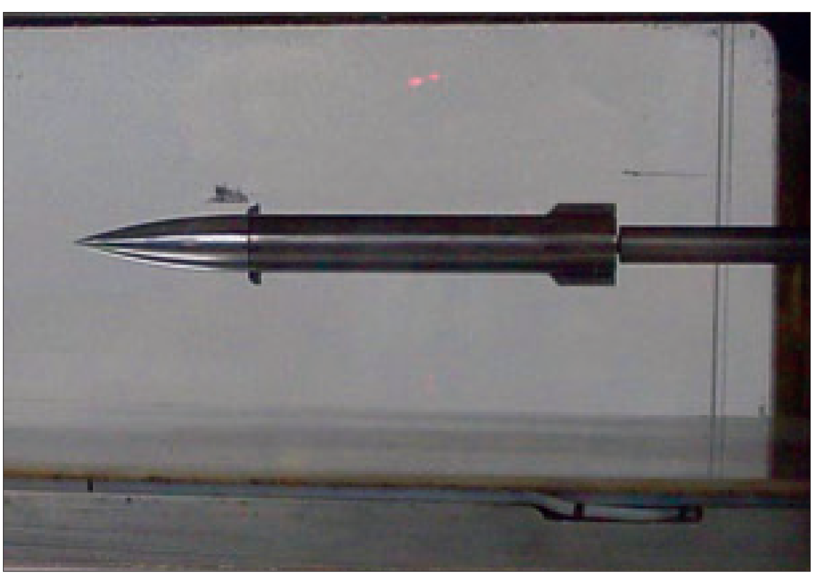
With the U.S. military committed to developing and using alternative energy sources derived from plants and waste products, and international and domestic airlines finding these new fuels to be a seamless replacement for jet fuel, higher demand should lead to increased production, which should ultimately lead to lower prices.

Nevertheless, you may not want to be be downwind of the airplane flying on chicken fat and used french fry oil.

Elaine Camhi
Editor-in-Chief

# Adaptive structures

In March of this year the first adaptive flight control mechanism for a guided bullet, a piezoelectric steerable bullet developed at the University of Kansas, was granted a U.S. patent. This solid-state adaptive actuator uses a bender beam configuration to induce canard, fin, and/or wing deflections on munitions from 4 to 40 mm in caliber. Unlike conventional linear adaptive actuators, the LNPS (low net passive stiffness) PBP (postbuckled precompressed) actuator assembly induces deflection amplification with no loss of blocked moment capability. Bench, wind tunnel, and shock table tests demonstrated all critical components and functionality. At a low unit cost in high volumes, the actuator is considered an ideal candidate for a number of current and future small- and mid-caliber steerable munitions projects.



*A steerable adaptive bullet awaits Mach 3 testing in a supersonic wind tunnel.*

Also in progress are several efforts investigating adaptive structures for rotorcraft. Researchers from Boeing, Sikorsky, and Bell-Boeing are developing next-generation mission adaptive rotor (MAR) systems for helicopters. The goals of this DARPA-sponsored program are to use technologies that enable the adaptation of the rotor and thereby to provide an expanded operating envelope with significant improvements in payload, range, noise, and vibration. The current development effort includes conceptual design, technology maturation, and formulation of system requirements. Adaptive features considered include blade shape changes, individual blade control, and variable rotor speed. Planned future program phases include development and ground, wind tunnel, and flight testing of a full-scale rotor system.

As part of a technology investment agreement with the Army, Sikorsky recently demonstrated the performance, vibration, and noise improvements of a helicopter rotor system with active trailing-edge flaps in the National Full-scale Aerodynamics Complex 40x80-ft wind tunnel at NASA Ames. In addition, Sikorsky and the Army are developing an active-rotor hub-mounted vibration suppression system that will undergo flight testing in early 2012.

The Adaptive Structures Team in the Air Vehicles directorate of the Air Force Research Laboratory spent the past year conducting research in several areas. Nanoparticle doped shape memory polymer (SMP) rods were fabricated to support investigation of a thermally activated reconfiguration system. SMP rods with different nanoparticle volume fractions were investigated to tailor a passive actuation time control by changing thermal conductivity with doping. A table top test rig was built to demonstrate the concept and tested. They are continuing to investigate perching micro air vehicle concepts, particularly in initial planform shape and size studies and prototype development of a perching mechanism.

Work also continues in the field of structural health monitoring (SHM). Under a project funded by the Air Force, Clarkson University and the Indian Institute of Science are jointly developing wavelet-based spectral finite elements (WSFE) for wave propagation in damaged composite structures. Use of compactly supported wavelet basis functions allows treatment of finite boundaries and yields very efficient computational models. The WSFE approach is highly suitable for solving the inverse problem of SHM.

Arizona State University, through funding by the Air Force Office of Scientific Research, the Army and Air Force Research Laboratories, and NASA Glenn, developed a multidisciplinary framework for SHM and prognosis. A reference-free, guided wave-based approach has been developed for damage localization. Residual useful life prediction is based on on-line and off-line estimation. Applications include aircraft hotspot, satellite structure, and complex composite structures with braided architecture.

by **Louis R. Centolanza**

# Design engineering

Aerospace design engineering continued to witness advances in design processes and multidisciplinary optimization with a strong influence on manufacturing and rapid prototyping. The time between conceptual design and manufacturing continues to shrink as the tools and processes for design become the same as those for manufacturing. This evolution continues to manifest itself in many existing and new endeavors.

The space shuttle program ended this year with the last flight and retirement of the shuttle fleet. The program had used improvements in design and manufacturing processes to keep the fleet in service and to accommodate advances in missions, payloads, and subsystems. The shuttle has been the workhorse of the U.S. space program and will be missed. With its retirement, many companies and consortia are competing to replace it with vehicles for transporting crew to and from the ISS and other LEO operations. One such vehicle concept is the Boeing CST-100 space capsule, designed to take as much advantage of existing launch and subsystems as possible to expedite a return to space for U.S. crews. Boeing has successfully completed initial reviews of the new capsule and is planning for initial flight tests as early as 2014.

Honda has entered the personal and business jet market with its HondaJet. Initial flight testing began in 2010 and the first FAA configuration jet began flight tests this year. In this innovative design the plane's engines are mounted on the wing but above and aft of it, rather than on the fuselage. This feature reduces drag, increasing overall efficiency and performance. It also allows for more room inside the cabin. The HondaJet team has used advanced design techniques to develop a composite cabin structure mated with single-sheet aluminum wings, further increasing efficiency by reducing airframe weight and drag. FAA certification of this unique design is expected to be completed in 2012, with initial deliveries soon after.

Unmanned combat systems took a large step toward reality this February with the first flight of the X-47B UCAS-D (unmanned combat air system demonstrator). The airframe's unique configuration combines a kite planform and a flying wing (called a 'cranked' wing). This design provides an optimal balance of fuselage length, propulsion installation, and integration of the weapons system with the aerodynamic flying qualities needed for carrier operations. Development of the X-47B used many rapid prototyping techniques, including one such use in initial wind tunnel testing. Stereolithograph models were used for initial configuration diagnostics where any changes could be made and tested quickly. SLA components were also used in the high-speed (and high-stress) wind tunnel tests. Flight testing and system analysis will continue over the next several years as carrier operations with the aircraft are assessed and validated.

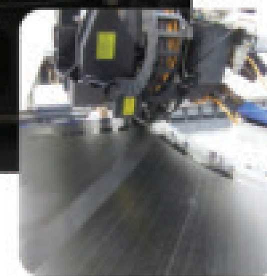
*The X-47B made its maiden flight in February.*

Rapid prototyping techniques have been available to design engineers for over two decades, but have been limited mainly to nonfunctional parts used for geometry verification and assembly trials. Advances over time have yielded better materials and processes that enable some components to be made as functional and affordable hardware. However, these have typically been limited to parts that are nonstructural or of low functionality. Now the process of additive manufacturing has evolved to the point where fully functional, structural components can be affordably manufactured from many traditional materials. This allows the design engineer to remove material that could not be removed by traditional machining techniques, reducing weight, thus lowering the operating expense of aerospace structures.

One research firm has identified as many as 1,000 parts on an Airbus aircraft that could be manufactured using this process. And as the 'printers' used to create these parts become more and more affordable, look for more to be incorporated into existing and new designs.

by **E. Russ Althof**

# Materials

*A 5-m-radius composite sandwich panel fabricated by Hitco uses automated manufacturing technologies and out-of-autoclave processing.*

Research supporting the development of structural materials at multiple length-scales and in various material forms continues to impact current and future vehicles.

NASA's lightweight spacecraft structures and materials (LSSM) project is developing composite structures and materials technology for heavy-lift launch vehicles. This year, LSSM focused on automated tape placement of autoclave and out-of-autoclave materials. As a significant part of the project, Hitco in Gardena, California, has successfully completed the fabrication of six aluminum honeycomb/composite face-sheet panels that are representative of composite fairing structures and are 1/16th-arc of a 10-m-diam. barrel (about 2x3 m). Testing of specimens cut from these panels shows promising results. LSSM transitioned to the Composites for Exploration (CoEx) Project at the start of FY12. CoEx has begun fabrication of a tool for larger panels sized at 1/6th-arc of a 10-m-diam. barrel (approximately 5x6 m).

Another advance in sandwich composite materials came from the Automobili Lamborghini Advanced Composite Structures Laboratory at the University of Washington, with help from the Northrop Grumman Unmanned Systems Development Center. The lab is researching bonded scarf repair of thin-gauge carbon fiber composite honeycomb panels commonly used in UAV structures. The use of advanced optical full field strain measurement techniques, such as video image correlation, has allowed the researchers to better understand the complex strain distribution of the sandwich panels under four-point bending loading. With traditional strain gauges, the data acquired would not sufficiently capture the variation of strain surrounding the repair area, which comprises a core plug, surface plies, and, in some cases, top cover plies. This technology has enabled researchers to tailor the repair to match the stiffness of the surrounding material and to limit the amount of strain concentration at the edges of the repair.

NASA's exploration and aeronautics programs are developing another composite material form, advanced rigid ablators, to substantially increase reliability, decrease mass, and reduce the life-cycle costs of rigid aeroshell-based entry systems. Advanced rigid ablators combine ablation-resistant top layers capable of withstanding the high heat flux of high-speed atmospheric entry with an insulating mass-efficient bottom that insulates the structure and lowers the areal weight. These materials may benefit vendors of commercial orbital transportation services and may enable new NASA missions that require higher velocity returns (from asteroids or Mars, for example). The materials have been thermally tested to 400-450 W/cm$^2$ at the Laser Hardened Materials Evaluation Lab, Hypersonics Materials Evaluation Test System, and several arcjet facilities. Tested materials exhibit much lower back-face temperatures and reduced recession over the baseline PICA materials. Although one of the main funding sources (the NASA Exploration Program's entry, descent, and landing project) ended in FY11, NASA in-house development of advanced ablators will continue, with a focus on varying resin systems and fiber/resin interactions.

Finally, researchers at the University of Texas at Austin and KAI LLC are conducting extensive research on polyamide 11 and 12 resin-type nanocomposites for selective laser sintering (SLS) additive manufacturing. Numerous nanomaterials, such as nanoclay (NC), carbon nanofiber (CNF), nanosilica, nanoalumina, multiwall carbon nanotube (MWNT), and nanographene platelet (NGP), have been incorporated into PA11 and PA12 polymers. Recent results indicate that 2-3wt% MWNT in PA11 can achieve attractive electrostatic dissipation levels. Combined low levels of NC, CNF, and intumescent flame retardant additives in PA11 provide a UL 94 V-0 rating. PA11-NGP nanocomposite also shows great promise and is currently in development. Conductive PA11 nanocomposites and FR PA11 nanocomposites will enable SLS additive manufacturing to enter new segments of aerospace and commercial markets.

by **Edward H. Glaessgen**

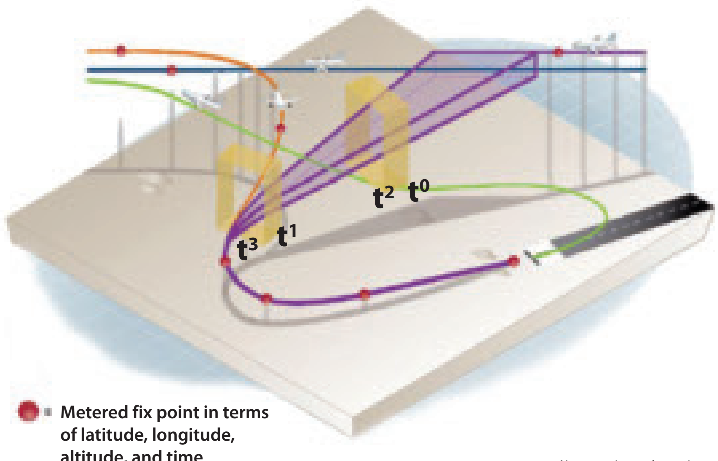
# Nondeterministic approaches

Nondeterministic approaches (NDA) refer collectively to mathematical tools that enable engineers and scientists to account consistently for uncertainty and variability in modeling, design, construction, testing, and maintenance of engineering systems. Complex engineered products are more likely to meet performance requirements when NDA are used. Consequently, NDA continue to find increasing application across different disciplines, although their role is often not recognized. Looking 'under the hood' of two technologies of significant interest to the aerospace community we can see the role of NDA in both.

Aircraft structural health management has always relied upon NDA. Historically, it was sufficient to know the time to some percentage of units' failing in order to schedule preventive maintenance or replacement. The increasing cost and complexity of current aircraft structures have created a need to perform maintenance when it has the most benefit. Advances in electronics have made it practical to place sensors permanently on the airframe to record strain histories or sense the presence of cracks and other damage. NDA techniques such as reliability-based design optimization help to determine the best locations for the sensors by identifying where damage is most likely to develop.

NDA can also be used to establish the best strategy for combining on-board sensing with traditional nondestructive inspection methods. Determining the probability of detecting damage and of not detecting damage is critical to assessing the accuracy of the structural health assessments.

The health of the aircraft structure is presented as a probability distribution of the remaining useful life. After a structural health assessment, the remaining useful life distribution is updated with NDA by applying Bayes equation to the previous health state and the results of the current assessment. The prognosis for the aircraft requires probabilistic crack growth and damage progression models accounting for variability in material properties to forecast the future health state. The load and environmental events that are the forcing functions for these models are themselves forecast using probabilistic representations of how the aircraft will be flown in the future.




*Four-dimensional trajectories in the NextGen Air Transportation System will be used in planning and executing flight operations.*

Management of the Next Generation Air Transportation System, or NextGen, will use NDA for trajectory-based operations (TBO) within the air traffic management (ATM) process. TBO uses 4D trajectories (4DT) as the basis for planning and executing all flight operations. A 4DT is a precise flight profile in space and time that includes the 'centerline' of a path plus the position uncertainty using waypoints as specific steps along the path. The uncertainty in aircraft position at a given time, in departure and arrival times, and in the time to specific waypoints must be represented mathematically to enable the ATM system to automatically and dynamically negotiate 4DTs between aircraft and to maintain safety. If uncertainty is not considered in establishing the 4DT for an aircraft, the ATM system could end up renegotiating a large number of 4DTs every time an aircraft gets the slightest bit off schedule.

Uncertainty in weather also needs to be considered in planning a 4DT. Otherwise a long-distance flight could require updating of the 4DT to avoid severe weather that developed while the aircraft was in transit. Making these decisions with uncertainty requires NDA. Before being implemented, the TBO-based ATM will need to be thoroughly verified and validated, which will require NDA as well.

As these two examples illustrate, NDA underlies many recent technological advances. The increasing complexity of technology drives the need for such approaches. Accordingly, numerous programs at NASA, AFRL, and the Navy use NDA. Efforts are also under way at the Dept. of Energy weapons labs and funded academic alliance partners to train engineers in all aspects of NDA.

by **Eric Tuegel**

# Structural dynamics

Boeing, under contract to DARPA on the Vulture II program, tested a very flexible wing semispan model in the low-speed Kirsten Wind Tunnel at the University of Washington. Static and dynamic response data were collected on the heavily instrumented model. The model design used static aeroelastic scaling laws and featured a cantilever installation and thus did not represent the flight dynamics of the full-scale vehicle. However, the model enabled the study of dynamic stability about highly deflected conditions. During the test, a wing tip deflection of approximately 40% of the 9-ft semispan was achieved. The data collected will be used in correlation and validation of high-fidelity nonlinear aeroelastic analysis models supporting high-altitude long-endurance aircraft design.

*Sandia has constructed two Ampair wind turbine test beds like this one to investigate methods for coupling experimental models of the rotor to finite-element models of the tower and nacelle.*

Sandia National Laboratories has continued research in experimental dynamic substructuring, model validation, and structural acoustics prediction. An experimental dynamic substructuring focus group was formed with support from the Society for Experimental Mechanics with more than 20 international researchers. Sandia is leading the effort and has constructed two Ampair wind turbine testbeds for investigating ways of coupling experimental models of the rotor to finite-element models of the tower and the nacelle.

Sandia continued research in developing procedures for the validation and propagation of uncertainties in high-fidelity structural dynamic models. Analytical investigations into the nature of the acoustic field generated during direct field acoustic testing has shed light on the source of discrepancies between modeling and experimental data. The investigations have led to use of the structural acoustics capability in Sandia's Salinas code to model the actual test, design future experiments, and reduce the risk of overtesting.

At NASA Marshall, structural dynamics personnel are performing advanced analysis for turbomachinery in the J2X, the rocket engine under consideration for the new space launch system. One of the program's most challenging analyses is predicting turbine blade structural capability. Resonance was predicted by modal analysis, so comprehensive forced response analyses were initiated using high-fidelity cyclic symmetric finite-element models. Initially the flow field was assumed to cause identical loads on every blade as each traveled through the flow. However, in the J2X the CFD flow field varied over a single revolution because of the flow speeds and tortuous axial path. Therefore, NASA Marshall developed a complex procedure using Nastran Dmap and Matlab scripts to apply this circumferentially varying loading onto the cyclically symmetric structural models. This resulted in more accurate dynamic stress prediction due to static, spin, and thermal loadings.

The Air Force Institute of Technology investigated the dynamic forced response of the forewing of the Manduca Sexta (moth) under various loading conditions through analytical and experimental methods. The goal is to improve modeling and simulation of the biological system to attain a better understanding of the wing's critical structural features for use in future bioinspired designs.

NASA Glenn has taken ownership of the Reverberant Acoustic Test Facility (RATF) and the Mechanical Vibration Facility (MVF) in the Space Power Facility at Plum Brook Station in Ohio, along with SAIC-Benham, the prime contractor for both facilities. The RATF and MVF test capabilities augment the Space Power Facility thermal vacuum chamber to provide one-stop environmental testing that supports future space missions for both NASA and industry.

The RATF's very high acoustic power and very large test volume (101,000 ft$^3$) are unique among the world's reverberant acoustic test chambers. Final acoustic verification testing in September included the successful test demonstration of commercial launch vehicle acoustic spectra and levels. When finished, MVF will be able to accommodate an 18-ft-diameter, 75-ft-high test article weighing up to 75,000 lb for fixed base modal testing. Also, sine testing up to 1.25-*g* vertically and 1.0-*g* horizontally from 5 Hz to 150 Hz can be conducted, with no need for reconfiguring the test article between test axes.

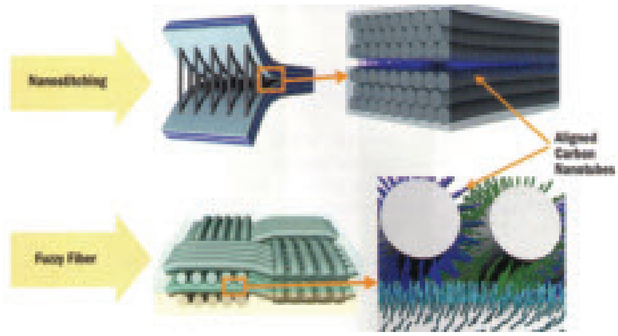
by the **AIAA Structural Dynamics Technical Committee**

## Structures

The Advanced Composite Cargo Aircraft program at Wright Patterson AFB Laboratories designed, developed, and manufactured the X-55A airframe during 2007-2009. The X-55A is a highly modified Dornier Do 328; the fuselage aft of the pilot cabin and the vertical fin have been redesigned and manufactured using advanced composite material featuring primarily bonded assembly. The redesigned fuselage is approximately 20% larger than that of the original Do 328 because of a widened cargo area and an aft-opening cargo door. The aircraft features widespread use of MTM-45 out-of-autoclave resin composite.

During the summer of 2010, the X-55A completed 12 basic envelope expansion flights, finishing 263 of 266 planned test points, and accumulating approximately 25 hr on the airframe. Aircraft flight performance was very much as expected, with minor deviations from the baseline Do 328 attributed to the cargo door/beavertail configuration. Structural performance was monitored during these flights, and no anomalies were noted. The X-55A is currently in storage and will be available for future test efforts. Plans to manufacture and test durability, damage tolerance, and residual strength on a full-scale fatigue test article based on the X-55A fuselage, and using identical out-of-autoclave materials and manufacturing processes, were deferred to 2012 because of manufacturing and budget issues.

The Air Force Institute of Technology's Department of Aeronautics and Astronautics is continuing research on development and testing of flapping wing micro air vehicles (FWMAVs). To determine control forces and moments, the FWMAV prototype is tested on a micro six-component balance. Each wing is individually controlled using a piezo actuator and novel control technique: biharmonic amplitude and bias modulation control, which consists of three independent wing stroke parameters per wing. Various micromanufacturing techniques were developed to create wing structures, hinge mechanisms, piezoelectric actuators, and support assembly. The control effectiveness of the prototype is currently being evaluated, with a near-term goal of tethered controlled flight demonstration. Structural dynamic features of the wing are also being evaluated from a nonlinear point of view.




*This two-level laminate nanoengineered composite is made from hybrid materials with aligned carbon nanotubes.*

An MIT/Airbus/Boeing cooperative team is developing composite materials to replace metal flight structures and decrease production costs. Carbon nanotubes (CNT) are cylindrical carbon molecules a few nanometers in diameter, 50 times stronger and 10 times lighter than steel, with hundreds of times the electrical conductivity of copper and three times its thermal conductivity. They are being used in development of conductive composites and multifunction materials to provide high strength/weight ratio structural components where carbon fibers provide dual structural and electrical functions. These materials are being manufactured by inserting nanoparticles into substrates and then chemically growing nanotube forests. Other project phases deal with spinning microfibers from CNTs to produce hybrid fibers in nanotubes.

At the NASA Langley Engineering and Safety Center, efforts to develop improved new shell-buckling knockdown factors will result in vehicle weight savings and more reliable failure conditions for launch vehicles. Extensive large-scale tests of composite structures are under way in cooperation with Boeing and Northrop Grumman. Typical of these experiments are shell-buckling tests of a 27.5-ft-diam. space shuttle external tank barrel conducted at NASA Marshall. The purpose is to validate the scalability of the new analytical design factors.

At the University of Illinois at Urbana-Champaign, in cooperation with Boeing's Advanced Structures R&D Group at Huntington Beach, California, research programs on analyses of designer materials and geometries are leading to optimized efficient lightweight structures. These tailored/engineered materials are being specialized for direct application to the PRSEUS (pultruded rod stitched efficient unitized structure) composites.

by **Harry H. Hilton**

# Survivability

by **Ameer G. Mikhail, Gregory J. Czarnecki,** and **Alex G. Kurtz**

The U.S. space program and NASA faced difficult technical, political, and budgetary dilemmas for their future space exploration efforts, in terms of both the general goals and the manned vehicle program. With the retirement of the space shuttle fleet and the uncharacteristic interim reliance on Russian/foreign and private space companies for transportation to the ISS, there are serious concerns about the reliability and survivability of both the capsule vehicle, with its precious cargo of astronauts, and the launch rocket itself.

For example, the original NASA Orion capsule/vehicle was the only capsule that was safety-certified by NASA for crew transportation. The agency now has to certify any new Orion-type designs (now known as the multipurpose crew vehicle) submitted by any private company, as NASA's role is politically mandated to shift from a designer/developer to a monitor and certifier. NASA has been, and still is, formulating a set of "human rating standards/requirements" to assure the proper design as well as safety and survivability for astronauts on all new commercial capsules and rocket systems. This updating of standards continues, a work-in-progress for the near future.

Laser weapons of both high and medium strength are a threat to large and small aircraft. The Air Force at Wright-Patterson AFB recently investigated laser effects on fuel-backed aircraft composite materials immersed in a high-velocity airstream. The goal was to conduct a test, the first in its kind, of a composite wing box under fully controlled test conditions that included laser engagement during simulated flight.

In order to obtain the necessary test approvals for these weapons, in-lab tests supported by modeling addressed fundamental questions concerning target surface reflectivity, laser burn-through time, energy absorption due to the fluid-backing, and the presence of an airstream. Simultaneously, the USAF airflow test facility was reconfigured to create a fully enclosed test operation, complete with laser energy blocks. After the approval, three laser tests were performed on a single composite wing box from an unmanned aerial system.

The first two of these tests avoided the fuel tank and were performed merely to verify laser system stability and burn-through times in the presence of an airstream. The final test involved direct impingement on the fuel tank. Successful completion of the three tests served as a demonstration of safe laser operations needed for future assessments of aircraft vulnerability. The test procedure will now transition to assessing the survivability of other military assets against this threat.

*A large turbofan engine mounted on a test stand awaits MANPADS testing.*

Large turbofan engines of both civilian and military aircraft are vulnerable to man-portable air defense system (MANPADS) missiles. An important first step toward countering this threat is to understand and determine likely engagement outcomes. Thus the Air Force, Navy, Dept. of Homeland Security, and NASA Langley have teamed to assess the missile's encounter with a large transport aircraft. Testing involves firing live-warhead missiles into each of two turbofan engines operating at full thrust. Work completed during the past year includes generating high-fidelity predictions of the engine damage and provisioning for the test.

This effort also included preparing the test plan, fabricating the test fixture, designing an engine controller, preparing and instrumenting engine test articles, and conducting system checkout tests. Upon the conclusion of each engine test, thrust degradation characteristics and end damage states will be assessed, correlated with damage predictions, and used to evaluate the aircraft's controllability and its ability to perform a safe landing.

Another USAF project investigated the effect of intense but brief fire exposure on fiber-reinforced composites in aircraft structures. Other efforts were made to determine the level of structural damage a light mobility aircraft wing would suffer in a ballistic threat-induced fuel tank ullage explosion.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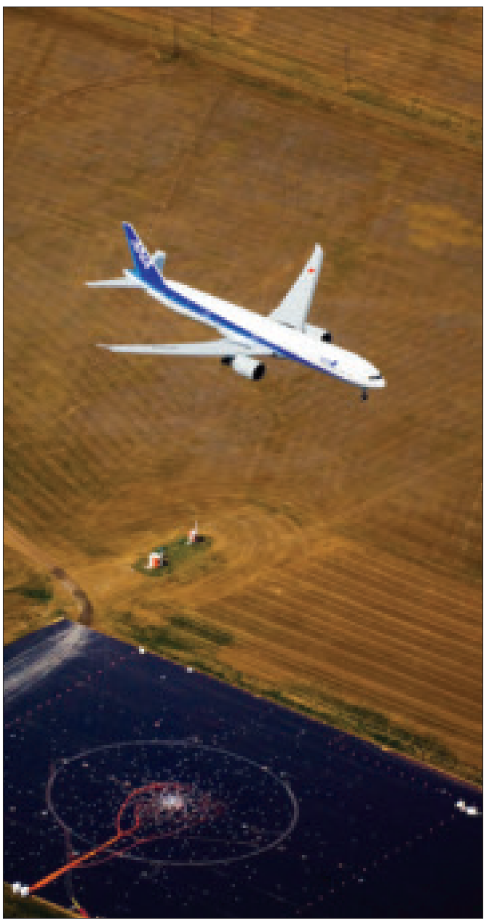
# Aeroacoustics

The International Civil Aviation Organization is considering more stringent noise regulations for commercial aircraft, which would be quieter by approximately 6-9 EPNdB (effective perceived noise, in decibels) than Stage 4 levels, with an initial implementation date of around 2017. The pending noise rules have spurred a flurry of technical activities aimed at both gaining better insights into noise source mechanisms and developing low-noise designs.



A flyover noise test of Boeing's 787 aircraft used a ground array consisting of 614 microphones.

Predicting airframe and engine noise remains challenging; the move toward higher bypass ratio engines for improved efficiency and lower environmental impact has necessitated development of better prediction and measurement capabilities. A new curved flow duct facility at NASA Langley is now available for impedance eduction and assessment of acoustic lining attenuation. Spirit AeroSystems and Missouri University of Science and Technology have adapted a 2D (originally axisymmetric) finite-element modeling scheme to produce a quasi-3D propagation model for the curved rectangular duct of the NASA facility.

Honeywell and Airbus validated the use of linear acoustic liners within complex 3D aircraft ducting. They conducted tests of a dual-fan system with treated inlet and outlet ducting at Honeywell's new ramp noise test facility near Phoenix, Arizona. The facility includes an anechoic chamber with inlet and outlet silencers, and a large concrete pad that supports tests of uninstalled and installed gas turbine engines, motor-driven fans, and other aircraft systems. Test results compared favorably with predictions made using Actipole, an Airbus multipole boundary element method solver.

Aeroacoustic installation effects of an open rotor were studied in an extensive model-scale experimental campaign executed by Boeing in the Low-Speed Aeroacoustic Facility. The Boeing/NASA collaboration was funded by NASA's Environmentally Responsible Aviation project. The acoustics of a contrarotating open rotor simulator were measured in isolation, in various positions relative to a tube and wing configuration, and in various positions with a hybrid wing body configuration. Acoustic measurements from phased, in-flow, surface-mounted, and far-field microphone arrays documented the complex acoustic interactions between the open rotor and airframe.

Boeing developed a semicircular near-field cage array of microphones to characterize the sources of jet noise. The array spanned 31 diameters in the axial direction, encompassing most of the source region. Comprehensive space-time correlation measurements, over a wide range of jet operating conditions, revealed a strong source coherent over 12 diameters in axial extent, responsible for the noise radiation to the peak angular sector. The data were used to develop and validate a Florida State University analytical method for the projection of near-field data to the far field.

The superboom caustic analysis and measurement project, or SCAMP, successfully conducted a sonic boom experiment requiring precision-flown F-18 supersonic dive maneuvers over a 10,000-ft, 81-microphone ground array in the remote Mojave Desert. Supplementing the array were seismic sensors, an instrumented sailplane that measured focused booms above the planetary boundary layer, and microphones suspended below a blimp to capture the incoming waves. The acquired database will be used for validation of focused sonic boom prediction codes.

Wyle supported TEC in developing the environmental impact statements for West and East Coast basing of the F-35B for the Marine Corps. Wyle developed and applied advanced noise modeling tools that account for the flight and performance characteristics of the short takeoff and vertical landing aircraft.

The adverse impact of the noise generated by tactical fighter aircraft, especially for aircraft carrier operations, received attention from the Navy. Noise reduction goals for the near-, mid- and long-term were developed by the noise panel of the Versatile Affordable Advanced Turbine Engine program.

by **Krishna Viswanathan** and **Anthony R. Pilon**

# Aerodynamic measurement technology

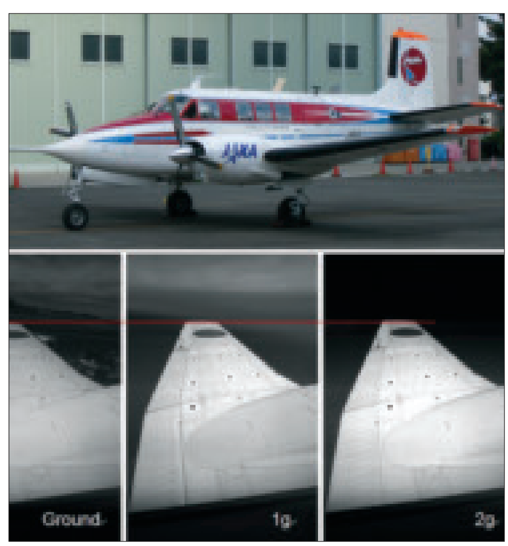
Pressure sensitive paint (PSP) has been demonstrated at high Mach numbers for measuring pressures on the surface of a model in unsteady flows in a shock tunnel at DLR, the German Aerospace Center. The test model was an 8.5-cm-long ramp coated with a luminophore layer. It was placed at an angle of 15° in a low-enthalpy Mach 7.4 flow. Images were taken at a frame rate of 5 kHz for 10 msec. Pressure measurements obtained with PSP on the surface of the model provided a color map of 2D pressure distributions. Comparisons with a conventional piezoelectric sensor were made, which showed that the response time of the chosen paint was sufficiently fast to allow faithful recordings of pressure changes.

Clear air turbulence presents a significant hazard to aviation. Michigan Aerospace is developing a compact airborne lidar instrument capable of identifying large-scale turbulent structures a few kilometers ahead of an aircraft. Modeling results indicate that the ranging lidar will provide the density field with resolution in the tens of meters. Augmenting this instrument will be a short-range lidar capability to characterize the turbulent field within the first 300 m ahead of the aircraft and to provide a complete optical air data solution.

Aerodynamic loads on an aircraft can result in wing twist, a factor that greatly influences the plane's aerodynamic characteristics. Therefore, in-flight measurement techniques for deformation of the wing are required during an aircraft's design phase. JAXA, the Japan Aerospace Exploration Agency, has been developing in-flight measurement techniques for deformation of aircraft main wings. They developed an analysis method and a measurement system that can provide the deformation data. The system optically measures the deformation of the main wing using high-resolution stereo imaging of position markers attached to the wing surface. The technique was applied to a twin-propeller airplane with no sweepback angle and succeeded in measuring the quantitative changes of both bending and twist angles.

Researchers at the University of Florida (UF), in collaboration with NASA Langley, have developed and characterized a MEMS-based direct shear stress sensor. The device is a dual-comb-drive floating-element sensor with a 1-mm sensing area. The sensor system showed a minimum detectable shear stress on the order of 1 milliPa. The device was placed into flat-plate boundary-layer models at both Langley and UF. Comparisons of sensor system results with PIV (particle image velocimetry) velocity profiles showed that the sensor system was able to accurately measure instantaneous wall shear stress in laminar, transitional, and turbulent boundary layers.

Researchers affiliated with the Combustion and Laser Diagnostics Research Complex at Wright-Patterson AFB have performed time-resolved, 50-kHz temperature imaging at the nozzle exit plane of an augmentor-equipped J85 turbojet engine. This work was a joint collaboration by Sukesh Roy and Andrew C. Caswell of Spectral Energies, Scott Sanders of the University of Wisconsin, Lin Ma of Clemson University, James R. Gord of the Air Force Research Laboratory, and David Plemmons of Arnold Engineering Development Center.




*A system developed at JAXA optically measures bending and twist angles of the main wing by stereo imaging of position markers attached on the wing surface.*

The group successfully applied a 30-laser-beam tomography system that used a high-repetition-rate hyperspectral laser source to measure water vapor absorption in the high-temperature exhaust stream. The laser source consists of three independent Fourier-domain mode-locked lasers with an overall repetition rate of 50 kHz. Tomographic reconstructions of the line-of-sight projections resulted in 255 spatial grid points of temperature measured per frame. The high-speed, spatially resolved technique permits studies of combustion instabilities and will be used to validate augmentor and nozzle CFD simulations.

by **Thomas P. Jenkins** and the **AIAA Aerodynamic Measurement Technology Technical Committee**

# Applied aerodynamics

NASA and the Army have begun detailed analysis and correlation efforts with data acquired during the 2010 UH-60A airloads wind tunnel test in the USAF 40x80-ft Wind Tunnel at NASA Ames. This test program provided a unique set of validation-quality measurements on a full-scale pressure-instrumented UH-60A rotor system at very challenging flight conditions, including high speed, high thrust, and slowed-rotor conditions. Key measurements available for correlation include blade pressures and loads, rotor performance, blade displacement and deformation, and rotor wake velocity measurements. Initial posttest efforts have verified the integrity and quality of the data and have helped to identify deficiencies in the CFD/CSD computational models. Further analysis and correlation are planned.

A new capability for ground testing active flow control concepts and propulsion simulations at flight Reynolds numbers has been implemented in the National Transonic Facility at NASA Langley. The FAST-MAC semispan model was used to test circulation control concepts over a range of Mach and Reynolds numbers. At low-speed, high-lift conditions, circulation control increased the maximum lift coefficient of a simple hinged flap by 40%. At transonic cruise conditions the circulation control favorably altered the shock-wave structure on the wing, and reduced flow separation. Application of blowing to the outboard portion of the wing demonstrated the feasibility of pneumatic-based roll control.

*NASA and the Army have begun detailed analysis and correlation efforts with data acquired during the 2010 UH-60A airloads wind tunnel test.*

The Air Force Research Lab (AFRL) and its partners completed critical experiments, validating technology maturation efforts for cruise-efficient short takeoff and landing transport aircraft under the speed agile concept demonstration program. Wind tunnel tests were conducted at the Arnold Engineering Development Center National Full-scale Aerodynamics Complex and the Langley National Transonic Facility to verify the aeropropulsive performance of the technology concepts, including a hybrid powered lift system. This system uses a novel Lockheed Martin patented device that provides thrust vectoring and reversing functions on the main engine exhaust flow and internally blown flap architecture on the outboard portion of the wing to enable lift augmentation and cruise drag reduction.

The AFRL revolutionary configurations for energy efficiency program focuses on developing technologies for reducing energy use. The Air Mobility Command is the U.S. government's largest fuel consumer and is looking to increase efficiency. Contractor teams completed parametric studies, modeling innovative technologies that improved overall mission efficiency for a system of new transport aircraft, such as high effective aerodynamic span and parasite drag reduction.

The NASA fundamental aerodynamics 'N+2' program worked with Lockheed/GE/Rolls-Royce/Stanford on next-generation supersonic concepts, focusing on low airport noise technology. A methodology linking parametric-CAD with CFD has been used successfully to arrive at conceptual design cross-sections that have low sonic boom characteristics.

The DOD 12-year CREATE (computational research and engineering acquisition tools and environments) program, established to enable major improvements in engineering design and analysis processes, seeks to develop and deploy scalable, multidisciplinary, physics-based computational engineering products for the design and analysis of ships, aircraft, and RF antennas. The air vehicles program, CREATE-AV, released three products in FY11: the fixed-wing design tool KESTRELv2.0, the rotorcraft design tool HELIOSv2.0, and the preliminary design tool DaVinci1.0. KESTRELv2 adds six-degree-of-freedom moving flap capabilities for realistic aircraft simulations. HELIOSv2 enables off-body adaptive mesh refinement and the ability to handle multiple rotorcraft components.

Applied CFD work at NAVAIR made impressive strides in predictive modeling of naval air vehicles. Examples of full-scale CFD simulation include coupled ship-air-wake/helicopter, time-accurate JSF shipboard recovery analysis, single-engine-out calculations using spinning props, modeling of a windup turn for the F/A-18E, and aerodynamic/propulsion analysis of Navy small UAVs to build a six-DOF autopilot.

by **Nathan Hariharan** and **Stephen LeDoux**

# Astrodynamics

This has been a year of exciting encounters. On February 15, NASA's Stardust-NExT probe 're-encountered' Tempel-1 and observed the changes in the impact crater created by the Deep Impact mission during its encounter in 2005. After the flyby, Stardust-NExT performed a 'burn-to-depletion' sequence to gather engineering data to be used for future spacecraft design.

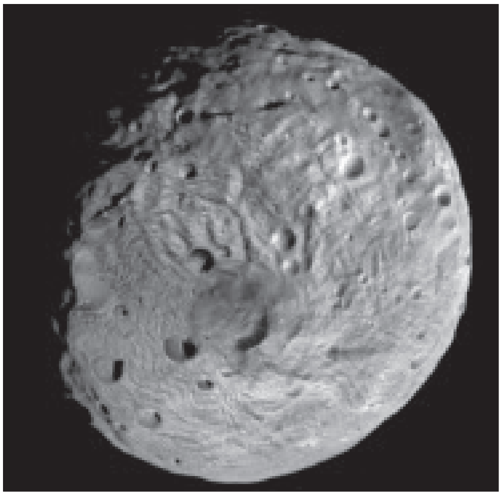
Launched in August 2004 and followed by six gravity assists at Earth, Venus, and Mercury, the MESSENGER (Mercury surface, space environment, geochemistry, and ranging) spacecraft entered orbit around Mercury on March 17, becoming the first spacecraft to orbit our solar system's innermost planet.

After nearly four years of solar electric propulsion cruise, on July 15 Dawn became the first spacecraft to orbit Vesta. More important, it is the first to use a low-thrust system to spiral in at an asteroid. Dawn will observe Vesta's surface composition and interior structure until it spirals out in 2012 and departs for its second science target, the dwarf planet Ceres.

After complex mission operations, the two ARTEMIS (acceleration, reconnection, turbulence, and electrodynamics of the Moon's interaction with the Sun) probes reached lunar orbit in July and will observe the Sun-Moon interaction for the next 7-10 years. China's second lunar probe, Chang'e-2, departed the Moon after completing its primary objective and reached the Sun-Earth L2 point. This made China the third country to have visited L2.

On December 7, 2010, Japan's Akatsuki spacecraft failed to enter its planned orbit around Venus due to underthrusting of its main engine. Akatsuki will attempt another orbit insertion burn when the probe returns to Venus in about six years. Launched from the same vehicle, the Japanese spacecraft IKAROS (interplanetary kite-craft accelerated by radiation of the Sun), the first successful interplanetary solar sail mission, accomplished all the mission objectives and has been extended to gather engineering data for future missions of this kind. The USAF's advanced extremely high frequency (AEHF) satellite had a major problem with its primary liquid apogee engine soon after launch in 2010. As an emergency plan, the satellite used its 5-lb Hall current thrusters to recover from the failure and to achieve its expected orbit altitude over a year's transfer time.

The shuttle Atlantis landed at the Kennedy Space Center on July 21, ending its final mission. This also ended the U.S. space shuttle program, after 30 years and 135 missions. For the next-generation program, NASA is designing and building the multipurpose crew vehicle and the heavy-lift SLS (Space Launch System) for future human exploration of the solar system.



*Vesta's south pole was captured by the Dawn spacecraft's framing camera from a distance of about 1,700 mi. Courtesy NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.*

Two historic observations took place this year. One was the discovery of an Earth Trojan asteroid, designated 2010 TK7. First detected by NASA's WISE (wide-field infrared survey explorer) mission, with follow-up observation by researchers at Athabasca University in Canada, the asteroid was shown to be stable for at least the next several thousand years. Farther away in the outer planet system, the Hubble space telescope discovered a tiny new moon orbiting Pluto, making it the fourth moon of the icy dwarf planet. This is an invaluable discovery for the New Horizons mission for planning close-up observations scheduled in 2015. On November 7 a near-Earth asteroid passed within 0.85 lunar distances from the Earth. Measuring 400 m across and named 2005 YU55, it presented an excellent opportunity for ground-based observations.

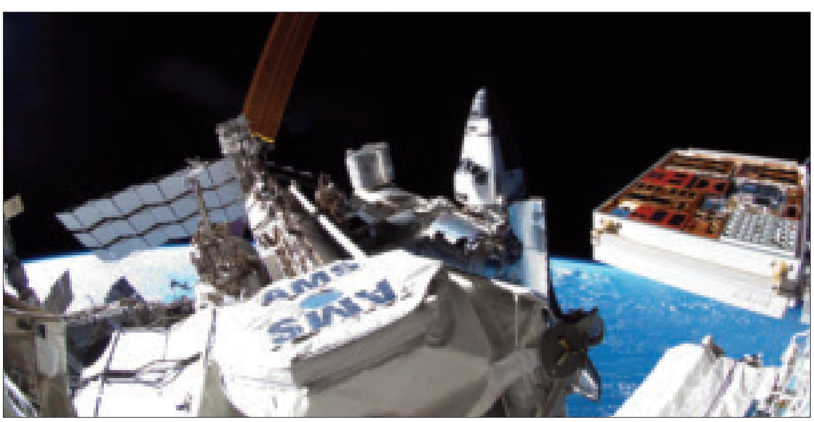
Finally, Moscow State University hosted the fifth global trajectory optimization competition. The objective of this international contest was to "make a rendezvous mission to a given asteroid most worthwhile by visiting the largest number of other asteroids on the way." This year's winner was a JPL team whose tour design consisted of 18 asteroid visits.

by **Ryan S. Park**

# Atmospheric and space environments

As Hurricane Irene forced a frenzy of disaster preparations in late August, Utah State University's Space Weather Center (SWC) worked to get ahead of the storm. The center's experts provided current and forecast HF (high-frequency) availability at their Website (http://spaceweather.usu.edu) and on their iPhone, iPad, and Android app, SpaceWx. SWC had provided similar information in March following the devastating earthquake and tsunami in Japan, where landlines and cell towers were destroyed and HF communication became the main link for emergency responders.

Solar storms have adversely impacted emergency communications before—in 2005, the fourth largest solar flare in history had disrupted rescue efforts after Hurricane Katrina.



*PASCAL (on the right) was installed on the ISS in May.*

Because of numerous jet engine power loss events believed to be caused by ice crystal ingestion, NASA and the National Research Council of Canada (NRC), with sponsorship by the FAA and Transport Canada, began experiments to examine the physical mechanisms of ice accretion on surfaces exposed to ice-crystal and mixed-phase conditions. The tests entailed placing a small wind tunnel containing a single wedge-type airfoil inside the NRC Research Altitude Test Facility. It has been determined that, under certain conditions, ice particles can accrete even though the local environment and surface temperatures are above freezing. Preliminary results suggested that the wet bulb temperature of the air (that is, the lowest temperature that can be reached by the evaporation of water only) could be a determining factor in whether or not hazardous ice accretions occur in the booster or compressor of an engine. Further tests are planned to investigate this finding.

The University of Alabama in Huntsville has developed a free tool that simplifies data mining of satellite imagery. GLIDER (globally leveraged integrated data explorer for research) provides an Eclipse plug-in-based software workbench with visualization and analysis tools that facilitate sophisticated analysis of satellite imagery. The imagery can be displayed in a 2D native swath view or overlaid on a 3D globe display. Visualization modes such as three-band color composite and look-up-table color display allow easy interactive image exploration and aid in identification of image features. Pixel level data can be plotted using scatter plots, histograms, spectral profiles, and spatial transect profiles, and can be interactively sampled and extracted from the imagery. The GLIDER software is available for download at http://miningsolutions.itsc.uah. edu/glider.

In May, the MISSE-8 (materials ISS experiment-8) payload was installed on the ISS. Included in the payload is the PASCAL (primary arcing of solar cells at LEO) experiment, supplied by Lockheed Martin, Kyushu Institute of Technology, and JAXA. Now operational, PASCAL is studying the cumulative effects of low-power electrostatic discharges on the operating characteristics of several modern space solar cell technologies by observing solar cell performance degradation as a function of number of arcs and arc energy, arc waveform shapes, and arcing inception/onset voltages for solar cell designs. PASCAL, and all of MISSE-8, will operate for approximately two years, with a return to Earth expected in early 2013.

Tests carried out at NASA Glenn indicate that the adhesion of lunar dust to spacecraft surfaces under ultrahigh vacuum conditions is dominated by electrostatic, rather than surface contact, forces. The adhesion of a synthetic volcanic glass to metallic structures was found to be much lower than to that of insulators such as polycarbonate and PTFE and FEP Teflons. These findings were verified by results indicating that a surface coating on FEP that minimized electrostatic buildup was more effective at reducing adhesion of lunar simulant dust in a simulated lunar environment than was surface texturing that lowered the contact area.

by **Dustin Crider**
and the **AIAA Atmospheric and Space Environments Technical Committee**

# Atmospheric flight mechanics

The NASA AirSTAR (airborne subscale transport aircraft research) system enabled flight research using a 5.5% dynamically scaled and remotely piloted generic transport airplane. Use of an unmanned subscale vehicle allows the test results to be applied to full-scale airplanes without risking a manned flight test crew. The effort is part of the NASA Aviation Safety Program and includes research in flight dynamics modeling, real-time estimation of aerodynamic parameters, and adaptive flight control technologies. The AirSTAR research has focused on adverse flight conditions associated with extreme upsets and failure or damage scenarios that degrade an airplane's stability and control characteristics.

The research demonstrated real-time dynamic modeling and comparison of simulation results. Novel flight test maneuvers were designed to collect flight dynamics modeling data using optimized orthogonal multisine inputs. These maneuvers, which were suited for modeling nominal aerodynamics and extended flight-envelope aerodynamics, allowed simultaneous control effectiveness estimation of 16 individual control surfaces.

AirSTAR was also used in remotely piloted evaluations of several flight control algorithms during an offset-to-landing task conducted at altitude. Each algorithm was assessed using Cooper-Harper ratings and time-history measurements to determine suitability in preventing loss of control as stability and control characteristics were degraded using an in-flight simulation technique. The study found that the tested adaptive flight control laws performed better than the conventional linear control laws.

The Boeing Phantom Ray UAV completed the initial flight test in a 17-min flight that evaluated ground handling, flight control, navigation, and pilot interface. The test included a climb to 7,500 ft and a maximum speed of 178 kt, which demonstrated airworthiness and motivated additional flight tests of handling and mission capability. The fighter-size Phantom Ray is intended as a technology demonstrator and as a platform for developing future UAV and UAS technologies.

Boeing also is planning a flight of the high-altitude, long-endurance Phantom Eye UAV late this year. Phantom Eye uses two hydrogen-fuel engines and is designed to fly at an altitude of 65,000 ft with an endurance of four days. The initial flights will be without payload and are intended to evaluate the flying characteristics and system operation of the vehicle.

*Flights of NASA's AirSTAR aircraft were part of the NASA Aviation Safety Program.*

Lockheed Martin has continued flight test evaluation of the three F-35 variants, including demonstration of a vertical landing on the USS Wasp. Continued ship suitability testing will assess aircraft performance and handling qualities in a flight envelope that simulates carrier operations.

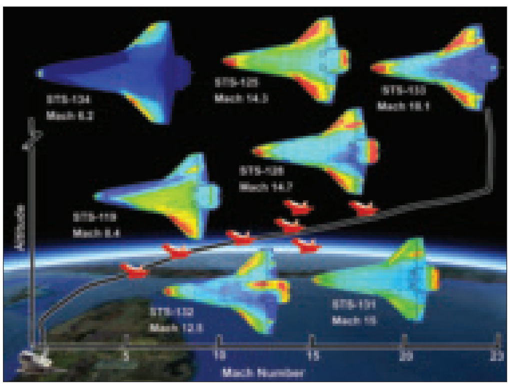
Hoh Aeronautics has received HeliSAS supplementary type certificates for the Bell 206B/206L/407 and Eurocopter AS350-B2/B3 and EC130. The HeliSAS is a digital stability augmentation system that can be retrofitted to existing helicopters and can both improve flight stability and reduce pilot workload. A reconfigurable version of HeliSAS was installed on a Bell 212 at the National Test Pilot School to be used as a training and evaluation tool in the flight control test and evaluation module.

The first reentry of The Aerospace Corporation's reentry breakup recorder (REBR) occurred on March 29 while the instrument was attached to the Japanese HTV2 supply vehicle, which had departed from the ISS. The REBR is a small autonomous device that records temperature, acceleration, rotational rate, and other data during the reentry of space hardware into Earth's atmosphere, and subsequent breakup due to aerodynamic heating and loads. REBR includes a heat shield that protects the instrument and its recorded data from the severe reentry heating environment. Recorded data are transmitted through the Iridium satellite network, and REBR recovery is not needed. This first-ever recorded data from an intentionally destroyed spacecraft enables validation of reentry hazard models, in support of DOD safety requirements. Future collection of additional REBR data will enable spacecraft and launch stages to be designed to minimize risks from surviving debris.

by **Mujahid Abdulrahim, Bruce Owens, Thomas Nicoll,** and **Daniel Murri**

# Fluid dynamics

This year brought many exciting developments in fluid dynamics, particularly in the areas of supersonic and hypersonic flow, flow control, boundary layers, and wind turbine interactions.




*Quantitative thermal imagery obtained by the Hypersonic Thermodynamic Infrared Measurements team provided a unique, never before observed perspective on the global distribution of surface temperature and the state of the boundary layer (laminar/turbulent) over the entire windward surface of the shuttle during portions of hypersonic reentry. Observations made over a period of approximately 2.5 years spanning seven shuttle missions covered the Mach range from 6.2 to 18.1.*

In a historic first, a high-resolution ground-based optical system positioned in Florida captured the progressive development and movement of thermal patterns on the shuttle Endeavour's lower surface resulting from hypersonic laminar boundary layer transition. Analysts at Johns Hopkins University will provide NASA researchers with quantitative global temperature distributions derived from these unique observations. Transition onset times and turbulent spreading characteristics will be used to tune engineering-based transition predictive capabilities developed during the shuttle return to flight program.

Researchers conducting experimental testing and numerical modeling will use the collective data from this mission and six others to characterize and reduce uncertainties associated with ground-to-flight extrapolation techniques and state-of-the-art computational prediction methods. The demonstrated remote sensing capability enables a next-generation imagery system with enhanced spatial/temporal resolution to complement flight testing employing the traditional discrete high-frequency surface instrumentation required for advancements in physics-based modeling.

Until recently, test and evaluation of hypersonic systems consisted of measuring integrated forces and moments. As a team, the Air Force Office of Scientific Research, DARPA, and Arnold Engineering Development Center have championed the refinement and integration of a suite of scientific research tools that have been implemented in AEDC's Tunnel 9. These provide a powerful new capability in aerothermal analysis. Engineers combined high-fidelity computations and stability analysis from the University of Minnesota, high-frequency pressure measurement practices from Purdue, and surface temperature-sensitive paint measurements from AEDC. This combination enables them to predict, measure, and document the global impact of boundary layer instabilities that drive significant heating phenomena on hypersonic systems.

NASA's entry, descent, and landing project is investigating supersonic retropropulsion (SRP) as an enabling entry system technology for human exploration of Mars. Wind tunnel testing was completed at NASA Langley to aid in the validation of CFD models needed to simulate the complex SRP fluid dynamics expected in flight.

Rolls-Royce and researchers at the Technische Universität (TU) Berlin demonstrated advances in active flow control for turbomachinery applications. Closed-loop control with pulsed-blowing actuation from the endwalls, combined with actuators on the suction surface of blades in a stator cascade, increased static pressure recovery and reduced the losses associated with secondary flow structures. This combination also increased the amount of flow turning that could be achieved.

Researchers from Illinois Institute of Technology, TU Berlin, and Caltech developed closed-loop control algorithms for gust suppression in a randomized unsteady freestream flow over a wing in a wind tunnel. The control system bandwidth was limited by fundamental time delays in the separated flow over the wing. Researchers at Princeton devised a new approach to reduced-order modeling of Wagner's indicial response function that will be useful for closed-loop control architectures.

Researchers at Caltech have demonstrated that small-amplitude, time-dependent changes to the roughness geometry of a continuous immersed surface (a 'dynamic roughness') can be used to obtain control authority ranging from the control of the lateral force profile in bluff body flow to manipulation of the characteristics of turbulent boundary layers. Associated modeling efforts are being exploited to predict actuation approaches that result in reduced skin friction.

Los Alamos National Lab is building a wind turbine field station to study turbine-turbine interactions at the 5-10-m scale. Recent diagnostics developed there, including large-field-of-view and rotating particle image velocimetry, promise to provide information on wake structure and blade separation. The field station will be open to researchers from industry, national laboratories, and universities.

by **Michael W. Plesniak**

# Ground testing

During the past year, the ground testing community has seen an interesting series of developments involving both facility upgrades and innovative test techniques.

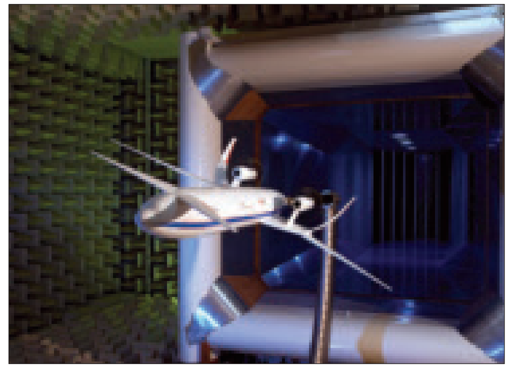
At NASA Langley, a dual-channel high-pressure air system has been installed in the National Transonic Facility that allows active flow control concepts and propulsion models to be tested at high Reynolds numbers. Meanwhile, the HYMETS (hypersonics materials environmental test system) was used for tests by the Mars entry, descent, and landing technology development project, an activity of the NASA Exploration Systems Mission. Several candidate ablative thermal protection materials were screened for survivability and performance in both the simulated Earth (air) and Martian ($CO_2$) entry environments.

At NASA Glenn, a low sonic boom supersonic inlet designed by Gulfstream Aerospace and incorporating a vortex generator-based flow control system developed by NASA and the University of Illinois at Urbana Champaign was tested in the 8x6-ft Supersonic Wind Tunnel. A four-phase test program on turbine-based combined-cycle mode transition was also started using the CCE-LIMX (combined-cycle engine–inlet mode transition experiment) testbed in Glenn's 10x10-ft Supersonic Wind Tunnel. The testbed enabled investigation of the mode transition between the low-speed turbine engine and the dual-mode ram/scramjet engine in combined-cycle propulsion systems.

At NASA Ames, two tests supporting development of the launch abort system for the Orion multipurpose crew vehicle were run in the Unitary Plan Wind Tunnel for Mach 0.3-2.5. The first test examined the stability and controllability of the launch abort system. The second test simulated its acoustic environment and provided fluctuating surface pressure data at over 200 points on the vehicle's surface.

At the Arnold Engineering Development Center in Tennessee, testing of the Pratt & Whitney F135 short takeoff/vertical landing variant propulsion system reached an important milestone with the successful completion of a high-temperature margin test.

New techniques developed at Calspan-University of Buffalo Research Center, or CUBRC, have enabled 'free flying' studies of full-scale scramjet vehicle performance and of the instabilities created during stage separation of high-performance interceptor vehicles. Meanwhile, CUBRC's large-scale LENS XX Expansion Tunnel became fully operational and was used to study the flow over capsule configurations and slender glide vehicles at velocities up to 10 km/sec.



*A major overhaul of the DNW NWB low-speed wind tunnel enabled it to conduct tests on items such as this model of DLR's Advanced Low Noise Aircraft.*

At the Aerodynamics Lab of the National Research Council Canada, several upgrades to the data acquisition and control systems of the 1.5-m trisonic pressurized wind tunnel were performed. The council is also continuing its development of pressure sensitive paint technology with a focus on low Mach/high dynamic pressure environments as well as unsteady flow fields.

In the U.K., a team of British and U.S. researchers developed a new methodology for boundary layer transition detection using temperature sensitive paint and validated it in the Aircraft Research Association's Transonic Wind Tunnel.

ONERA, the French aerospace lab, built and tested a new open-rotor test rig in association with Snecma in the S1MA high-speed wind tunnel. First results on the test rig have demonstrated that the test objectives of measuring propeller efficiency and acquiring acoustic data were fully met. Blade deformation was also measured during the test campaign.

At DNW German-Dutch Wind Tunnels, the low-speed wind tunnel NWB has become fully operational again after a major overhaul. This improvement enabled acoustic testing in both a closed and open test section with an anechoic plenum certified from 100 Hz to 40 kHz. Similarly, at the Japan Aerospace Exploration Agency, a new anechoic test section using Kevlar walls was installed in the agency's 2x2 m low-speed wind tunnel. These final examples are indicative of the growing interest in testing noise reduction technologies in production wind tunnels.

by **Julien Weiss**

# Guidance, navigation, and control

The Japan Aerospace Exploration Agency's Engineering Test Satellite-VIII successfully tested several novel robust attitude control laws, including mu-synthesis-based designs, a direct velocity and displacement feedback control law, and a linearly interpolated gain scheduling law. The goal is to develop a technical basis for the orbital control of future large flexible spacecraft.

*The Nano Hummingbird can fly for up to 10 min, streaming video back to a base station.*

Mango and Tango, the Prisma system's two spacecraft, feature relative GN&C components to control relative position and attitude. Mango has reaction wheels for attitude control and thrusters for relative 3D position control, including the first flight demonstration of a new micropropulsion thruster. Tango has only magnetic torquers for attitude control (no translation control actuators). For formation flight and approach/rendezvous demonstrations, Prisma uses GPS-based relative navigation, a formation-flying RF sensor, and a dual-use, vision-based sensor for close-in relative position/attitude telemetry that also serves as a miniature star-tracker. Prisma conducted numerous successful experiments in autonomous formation flight, RF-based formation flight, approach, rendezvous, and stationkeeping.

AeroVironment reached a milestone in DARPA's nano air vehicle program with the 19-g, 16-cm-wingspan Nano Hummingbird. The UAS can be independently controlled up/down, forward/backward, left/right, and in yaw by modulating the thrust and shape of the wings using four electric motors. It can fly both indoors and out for up to 10 min, streaming video back to a palmtop base station. It has demonstrated hover, forward flight at up to 11 mph, and even a 360° autonomous lateral flip. It has shown stability of hover in lateral wind gusts of up to 5 mph.

Boeing's Phantom Ray, an autonomous fighter-size UAS, successfully completed its first flight, which lasted 17 min. An adaptive augmentation control system enhances the aircraft's robustness to system uncertainties and its autonomous operations.

For the Army's joint precision airdrop system, software developed by Draper Laboratory enables clusters of guided parachutes to avoid terrain, and each other, during descent. The parachutes are fully autonomous during their entire descent; advanced onboard optimization-based guidance algorithms enable them to fly for several miles using onboard terrain databases for guidance around obstacles and for highly precise landings.

NASA Langley used the AirSTAR generic transport model, a 5.5% dynamically scaled, remotely piloted, jet-powered aircraft, to advance modeling and control at extreme parts of the air flight envelope. Use of the L1 adaptive control enabled real-time aircraft model parameter identification in the stall, poststall, and departure regions of the flight envelope in a single maneuver. Although the aircraft is not fully controllable in the departure region, the L1 adaptive control law enabled longer data acquisition time at these conditions and facilitated safe aircraft recovery.

DARPA held a second flight test of its Falcon Hypersonic Test Vehicle-2 (HTV-2), an unmanned, highly maneuverable, heavily instrumented 'data truck' designed to advance aerodynamic and aerothermal modeling and GN&C technologies in the hypervelocity flight regimes at speeds exceeding Mach 20. In August a Minotaur IV rocket boosted the HTV-2 to orbital insertion speeds on a low-elevation boost-path before release; after booster separation, the HTV-2 was designed to maneuver to perform a ballistic atmospheric reentry, execute a pull-up after pierce-point, then fly a long-endurance, in-atmosphere powered glide phase that includes maneuvers to help characterize its aerodynamic properties in high-speed regimes.

HTV-2 provided data through boost, apogee reorient, ballistic return, and atmospheric reentry. Ground control lost contact with the vehicle during its aerodynamic glide phase. HTV-2 had been modified after its first flight, moving its center of gravity, reducing angle of attack to increase controllability, and augmenting its aerodynamic control surfaces with RCS steering jets. Until loss of contact, HTV-2 demonstrated that it could maintain GPS lock through speeds of nearly Mach 20.

by **Luisella Giulicchi, Uday Shankar, Jonathan How, Irene Gregory,** and **Leena Singh**

# Meshing, visualization, and computational environments

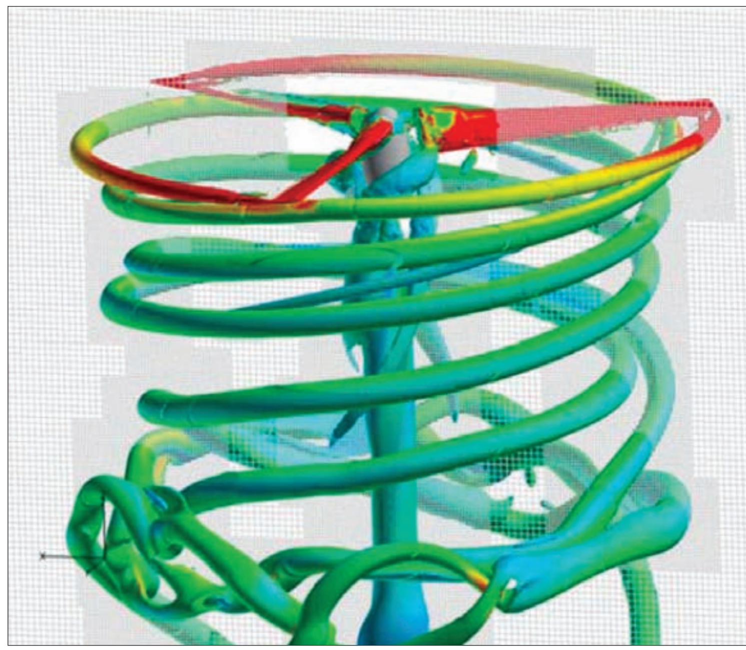
Over the past 30+ years, CAD has become the mainstay of the engineering community as it enables design ideas to be shared graphically. The role of CAD modeling has also become more prominent as CAD is increasingly integrated with computer numerical control (CNC) machines. CNC has made the fabrication of designs easier even for those without a high degree of machining skill, thus allowing an idea to leap from the designer's mind to the screen to production in a highly automated fashion.

While many CAD packages also include basic simulation tools, such as linear-elastic modeling for structural analysis, these tools are often limited by the size of the mesh that can be created on a common desktop workstation; by the ability to generate an appropriate discretization automatically; and by lack of availability of the source code. Many in the research community see the latter as a significant barrier to solution authentication. Because the user is not always certain of the methodology used in constructing the solution, its correctness and applicability are subject to question.

For those wishing to use CAD models for high-fidelity physics-based analysis and design, a painstaking manual process must be undertaken to make the CAD description 'watertight,' possibly to convert the file to an acceptable format for mesh generation, and then to generate a mesh on the discretized geometry. Adding to the difficulty is that many CAD engines and 'generic' file formats, such as .igs, are very limited in their ability to maintain features and parameters unique to the design's feature tree. However, the use of CAPRI, which was developed by researchers at MIT, has significantly improved that process by allowing the CFD user to interface with multiple CAD engines and access the feature tree remotely.

In addition, a significant research effort has been devoted to automating the CAD cleanup process and generating a high-quality surface mesh that resolves the geometry as realistically as possible. This produces more accurate solutions and direct transferability of design-optimized parts to fabrication. It also provides the mesh generation tool with an accurate, optimized geometric description with which to work.

On a different front, overset mesh generation has seen increased use due to optimized methods of interpolation and more available storage. Research codes such as SUGGAR++, which was developed by researchers at Penn State, have made their way into commercial software packages such as Pointwise, and organizations such as the USAF have taken notice and begun funding projects to streamline the use of overset methods for CFD analysis.



*TRAM solutions are generated with solution-based adaptation when the nondimensional Q method is used to guide the automated mesh refinement process. A Y-cut plane depicts the off-body grid, and the isosurfaces shown represent equivalent values of Q, which are colored by vorticity magnitude.*

Finally, adaptive meshing is always in the news, as much progress has been made in automating the process using increasingly complex mathematical models to generate metrics to refine or coarsen the mesh based on error estimates, flow features, and adjoint methods. Models such as the Lipschitz continuity function, Richardson extrapolation, particle behavior, and target matrices have debuted with highly robust results.

As processors become faster and memory becomes larger and more affordable, meshing, visualization, and computational environments continuously evolve to take advantage of the availability of new hardware technology. Truly dynamic adaptive meshing is attainable in the near term as the community converges on metrics and quality measures in support of activities such as the AIAA Drag Prediction Workshop and the Mesh Quality Workshop sponsored by DOD and AIAA.

by **Vincent C. Betro**

# Plasmadynamics and lasers

Research in plasma aerodynamics continued to expand this year. Meetings held by AIAA hosted a total of nine sessions devoted to the topic of plasma actuators, two on plasma-assisted combustion, and three on magnetohydrodynamic flow control.

There has been notable recent success in demonstrating plasma-based flow control in higher speed regimes. Notre Dame University has demonstrated control with alternating current dielectric barrier discharge actuators (AC DBDs) at high subsonic speeds (up to Mach 0.5) for a variety of applications, employing thick dielectrics and very high applied voltages. Ohio State University researchers have demonstrated control of bow shock standoff in a Mach 5 flow over a cylinder using nanosecond-pulse dielectric barrier discharge actuators (ns-DBDs). Princeton University and Spectral Energies have demonstrated femtosecond-laser-designed microwave power deposition in air, a promising technology for the supersonic and hypersonic regimes.

*The laser turret and testing configuration for the Airborne Aero-Optics Laboratory at the University of Notre Dame are carried aloft.*

There also has been significant progress in numerical modeling. The Air Force Research Laboratory (AFRL) has carried out implicit large-eddy simulations of the flapping wing of a micro air vehicle, using a serpentine AC DBD actuator for leading-edge stall control. At the University of Toulouse in France, researchers have replicated experimentally observed shocks formed with ns-DBDs. The effect is a result of fast electron-neutral energy transfer, a mechanism first identified by researchers at Moscow State University. AFRL and the University of Washington have demonstrated five-moment, three-fluid models of glow discharges. Tech-X has carried out 3D particle-in-cell calculations of ns-DBDs.

This year also saw the formation of the AIAA Plasma Aerodynamics Discussion Group, whose first meeting attracted attendees from academia, industry, and government, with representation from five countries. Initial discussions focused on shifting the orientation of the field from basic research to technology development, and on fostering cross-disciplinary communication and collaboration.

There was considerable activity on multiple fronts within the various areas of laser technology development. The Airborne Aero-Optics Laboratory at the University of Notre Dame, an in-situ facility for measurement of aerooptical aberrations and assessment of laser turret configurations, provided the first in-flight experiment data for a flat-windowed turret, an important contribution to the high-energy-laser community. These data, collected using a high-speed wavefront sensor with high temporal and spatial resolution, showed trends consistent with the known flow topology of turrets, namely increased flow separation and aerooptical aberration with angle rotation toward the aft. In addition, the data were shown to be scaled by normalization using the density and Mach number, providing a convenient means to connect low Mach number data to higher Mach number compressible data typical of the flight regime.

The DOD saw increased activity in efforts to develop weapons-class electrically powered solid-state lasers. The High Energy Laser Joint Technology Office, in collaboration with the Army Space and Missile Defense Command and AFRL, undertook the Robust Electric Laser Initiative, funding General Atomics, Lockheed Martin, Northrop Grumman, and Raytheon to develop high beam quality, 100-kW-class lasers as precursors to weapons-class systems. The Missile Defense Agency's Airborne Laser Testbed continued in-flight testing of the laser weapon, building on its missile shootdown successes in 2010. Extending efforts to develop electrically powered gas laser technology, researchers at CU Aerospace demonstrated scaling of electric oxygen iodine laser technology, substantially increasing laser power over previous efforts.

In a similar light, researchers at the Air Force Academy, AFRL, and Lawrence Livermore National Laboratory demonstrated further improvements in the hybrid gas-electric diode pumped alkali laser technology, which has the potential to supersede both solid-state and chemical laser technology with lower logistics footprints and higher efficiencies.

by **Timothy J. Madden** and **Jonathan Poggie**

# Thermophysics

Engineers in the Entry Systems and Technology Division at NASA Ames developed a fully instrumented small atmospheric entry probe called SPRITE (small probe reentry investigation for TPS engineering). Conceived as a flight testbed for thermal protection materials, SPRITE was tested at full scale in an arcjet facility so that the aerothermal environments the probe experiences over portions of its flight trajectory and in the arcjet are similar. This ground-to-flight traceability enhances the ability of mission designers to evaluate the margins needed in the design of thermal protection systems (TPS) for larger scale atmospheric entry vehicles.

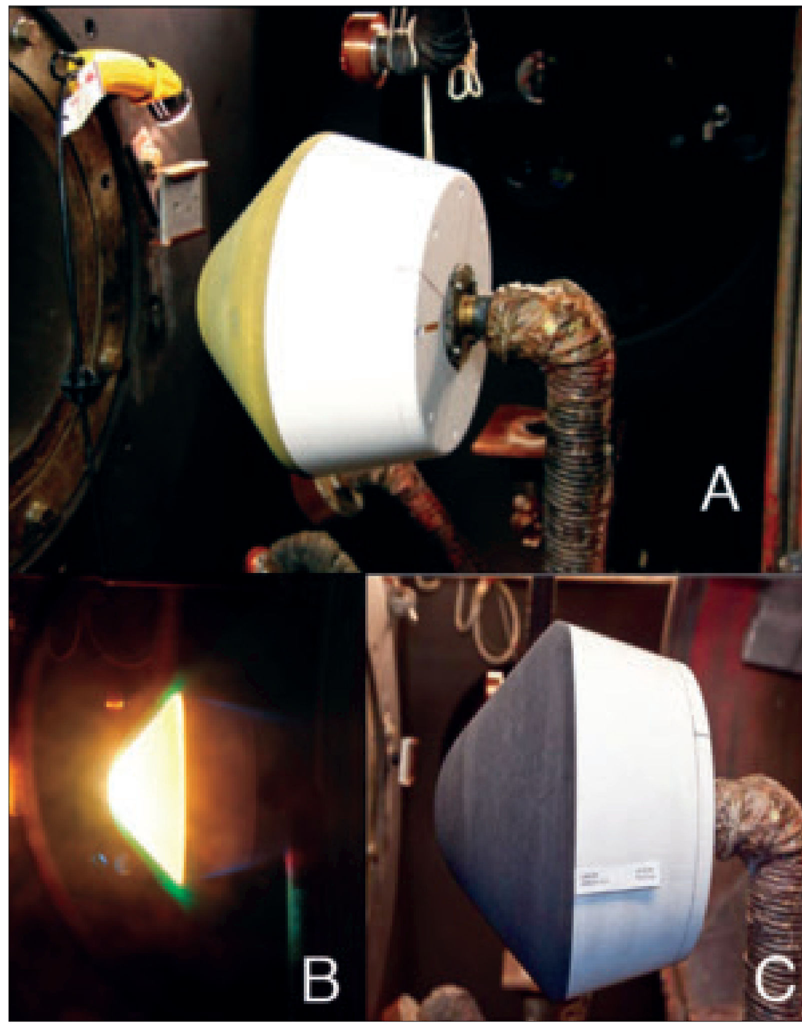
SPRITE is a 14-in.-diam., 45-deg sphere-cone with a conical aftbody and is designed for testing in the NASA Ames Aerodynamic Heating Facility. The probe is a two-part aluminum shell with PICA (phenolic impregnated carbon ablator) bonded on the forebody and LI-2200 (space shuttle tile material) bonded to the aftbody. Plugs with embedded thermocouples similar to those installed in the heat shield of the Mars Science Laboratory are integrated into the design, as are a number of distributed sensors. The data from these sensors are fed to an innovative, custom-designed data acquisition system that is also integrated with the test article.

Two identical SPRITE models were built and successfully tested in late 2010 and early 2011, and the concept is currently being modified to enable testing of conformable and/or flexible materials.

The NASA entry, descent, and landing technology development project is developing flexible ablative thermal protection materials to enable inflatable or deployable low ballistic coefficient entry systems for exploration at Mars. Use of these systems might also be extended to payload delivery at Venus, Saturn, and Earth.

The original flexible concepts were based on rigid ablator chemistry utilizing silica and carbon *flexible* substrates. More innovative approaches were developed concurrently and use polymeric and polymeric/organic flexible substrates.

Screening tests were performed on these materials with excellent results. The silica- and polymer-based materials easily survived aerothermal environments of 120 $W/cm^2$, and the carbon-based materials were effective in environments up to 530 $W/cm^2$. A second year of innovation has led to the generation of 15 different variants and improvements on these NASA-developed materials, together with five vendor-developed materials.



*A sequence of photos shows the SPRITE model before testing in a plasma flow (A), in the plasma flow (B), and after exposure to the flow (C).*

Given the performance of the carbon-based materials at high heat fluxes, it is envisioned that they may also substantially increase reliability and reduce life cycle cost of *rigid* aeroshell-based entry systems for multiple missions. The GCDP (game changing development program), an effort by Office of the Chief Technologist at NASA, has identified a need for the development of flexible ablative TPS capable of supporting exploration class missions. Based on the success of the work done in 2010 and this year under the project, this program will be funding further development in 2012.

by **Dinesh K. Prabhu** and **Robin A. Beck**

# Air transportation

The global airline industry has faced a challenging year, with higher oil prices and great economic uncertainty. However, buoyed by higher-than-expected passenger demand, especially in Asia, the industry is expected to earn a positive net profit for the year, though less than what was earned in 2010. Although this is a welcome development given current conditions, the industry still has a difficult road ahead in 2012 because of continued weak economic growth and stubbornly high fuel costs.


*The Boeing 787 Dreamliner was introduced into service this year.*

The rising cost of fuel and changing commercial transport business models continued to drive the design of more fuel-efficient aircraft with lower operating costs. However, the industry struggled over the tradeoff between developing wholly new models, which take substantial time and investment, and making major improvements to production models. This year the Boeing 787 and 747-8 were introduced into service, after overcoming substantial manufacturing and supply-chain challenges. In the narrowbody market, the late 2010 launch of a highly efficient reengined Airbus A320neo, and announcements of new entrants in the narrowbody market, pushed Boeing to announce its next new aircraft, the 737 MAX.

One way the airline industry has sought to maintain profitability is through mergers. The growing pains of recent mergers such as those of Delta/Northwest Airlines and United/Continental Airlines were felt this year, but both emerging companies are beginning to coalesce as they vie for the title of 'world's largest passenger airline.'

Higher fuel prices also spurred the development of more energy efficient air traffic operations. User-preferred management of traffic flow constraints, begun this year, will afford airlines flexibility in their operating strategies while still meeting system objectives. In addition, a field test of a new technology that enables continuous descents has demonstrated lower fuel consumption and reduced carbon dioxide emissions. The use of these tailored arrivals has cut fuel consumption and total carbon emissions during descent in Los Angeles, Miami, and especially San Francisco, where over 11,000 flights have benefited from this new technology.

ADS-B (Automatic Dependent Surveillance-Broadcast) technology is being utilized to reduce fuel burn and improve flight safety on transoceanic flights. ADS-B provides greater situational awareness of nearby traffic, which enables the in-trail procedure, in which aircraft use these data to find more favorable, unoccupied altitudes along the oceanic tracks. As a result, they can fly more efficiently while still maintaining safe distances from surrounding traffic.

Another change in traffic control has stemmed from the expanded use of unmanned aircraft systems (UAS) operations for both civilian and military purposes. UAS usage has increased both domestically and abroad in the past year, highlighting both advances and areas of improvement. At home, the Dept. of Homeland Security has expanded the use of UAS for border security to include counternarcotic activities. The Navy has integrated the MQ-8B Fire Scout UAS into operations on the USS Halyburton. This UAS has been used to chase pirates in the Indian Ocean, watch over troops in Afghanistan, and provide reconnaissance in Libya. The use of this aircraft has kept U.S. soldiers out of harm's way. One such example occurred when a Fire Scout was shot down during a scouting mission in Libya.

Highlighting the need for new control strategies, a drone was involved in a midair collision with a C-130 military cargo plane in eastern Afghanistan on August 15. Fortunately, there were no crew injuries, and the cargo plane was able to make an emergency landing with only minor damage. To that end, the Army demonstrated recent advances in manned-unmanned interoperability during the MUSIC (manned unmanned system integration capability) exercise in September.

by the **AIAA Air Transportation Technical Committee**

# Aerodynamic decelerator systems

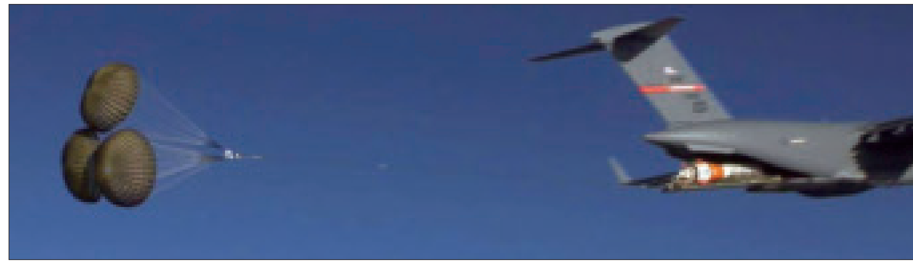
The field of aerodynamic decelerator systems has seen many exciting advancements this year. Aerial delivery remains an increasingly critical and successful method of delivering supplies safely, accurately, and rapidly to NATO forces. Airdrops in Afghanistan are projected to top 100 million lb by year's end. These resupply missions often support otherwise inaccessible locations. DOD leaders continue to support improvements in current airdrop capabilities and new airdrop technologies. The ongoing focus is to reduce system costs, increase accuracy, and expand the range of deployment conditions.

Two drop tests of the capsule parachute assembly system (CPAS) for the multipurpose crew vehicle (MPCV) were conducted to assess the performance of higher porosity main canopies. A third drop test in September included a representative parachute compartment. A series of full-scale CPAS ground tests also took place. JPL conducted a CPAS drogue parachute test program at the Texas A&M low-speed wind tunnel. The team flew 10%-scale conical ribbon parachutes in the wake of a scaled MPCV. High-speed video, time-resolved drag, and particle image velocimetry measurements were made to explore the coupling of the MPCV wake to parachute performance.

The Mars Science Laboratory parachute mortar system completed qualification testing. The flight mortars were delivered to Pioneer Aerospace for final assembly with the parachute packs. Following extensive reviews of the build and test data, the systems were approved by NASA JPL and the flight unit was shipped to Kennedy Space Center for integration and installation several months before the spacecraft's November launch.

A single 150-ft-diam. Ares main parachute was successfully tested at the Army's Yuma Proving Ground. The 72,000-lb jumbo drop test vehicle (JDTV) was extracted from a USAF C-17 aircraft at an altitude of 25,000 ft. The JDTV descended under a programmer chute until main parachute deployment. The total extracted weight was 85,000 lb, a record for C-17 single payload extraction.

Researchers from the Georgia Institute of Technology created a new canopy bleed air parafoil control mechanism for lateral and longitudinal control of autonomous airdrop systems. Flight test results indicate changes in glide slope from 3.0 to 1.0 and good turn rate control authority. At the University of Alabama at Huntsville, researchers have integrated multiple miniature wireless inertial sensors into a parafoil canopy and payload. Both rigid body and flexible canopy dynamics modes were identified using these sensors.



*An Ares main parachute was successfully extracted from a C-17 at an altitude of 25,000 ft.*

New commercial software and faster computing platforms have enabled the use of CFD, CSD, and FSI (fluid-structure interactions) simulations in parachute problems that until recently were deemed too complex and too computationally intensive for short-term efficient solutions. This year saw the first simulations of unsteady behavior, such as parachute inflation and landing speed reduction using pneumatic muscle contraction, by Airborne Systems, Saint Louis University, and DGA Aeronautical systems in France. Simulations of a cluster system showing the overall response and individual canopy motion were performed by Natick Soldier Research Center, Rice University, Bethel College, and the Universities of Connecticut and Texas-El Paso.

A NASA and industry team is working toward a 2012 launch date for the inflatable reentry vehicle experiment-3. The hypersonic inflatable aerodynamic decelerator (HIAD) consists of a cone-shaped configuration of seven braided inflatable tori, with a flexible thermal protection system to shield against the heat of reentry. The centerbody will provide inflation gas, telemetry, and a center of gravity offset system to generate lift. A HIAD can be used to deliver a larger payload than a traditional rigid heat shield, since its size is not limited by the booster shroud diameter. When launched, IRVE-3 will reach an altitude of 450 km and then reenter Earth's atmosphere at Mach 10.

For more information on the AIAA Aerodynamic Decelerator Technical Committee, please visit https://info.aiaa.org/tac/AASG/ADSTC/default.aspx.

by **Lauren S. Shook** and **John W. Watkins**

# Aircraft design

*The X2 technology demonstrator sets a250-kt cruise speed record, using its tail-mounted pusher prop. The helicopter's contra-rotating coaxial rotors slow as it accelerates.*

2011 was a busy year for aviation, marking significant accomplishments within the military and commercial sectors.

Sikorsky's high-speed X2 technology demonstrator completed flight testing, achieving its historic 253-kt level flight, and ushering in a new era of high-speed military helicopters. The X2 demonstrator used twin coaxial counterrotating main rotors and a pusher propeller to enable high-speed cruise.

The U.S. Navy celebrated the Centennial of Naval Aviation, and major milestones were attained in the area of carrier systems and UAS supporting naval operations.

Northrop Grumman's X-47B unmanned combat air system demonstration aircraft completed its first flight. A modified F/A-18D (using the X-47B precision GPS guidance and control laws) successfully completed shipboard surrogate testing aboard the USS Dwight D. Eisenhower. The aircraft achieved a completely automated (coupled) Case I approach to the deck of the ship using the PGPS and TTNT datalink systems. This was the first such approach in naval history. It was followed by the first coupled trap on a Case III straight-in approach and the first coupled trap on a Case I approach. The tailless fighter-sized unmanned aircraft is presently preparing for carrier-based flight tests.

The Navy completed its first aircraft launch using the electromagnetic aircraft launch system. This will replace today's steam catapult system on next-generation aircraft carriers to reduce maintenance and personnel costs.

Northrop Grumman continues development of the medium-range cargo-hauling VTOL Fire-X UAV and the composite bat-shaped Bat UAS, an affordable multimission modular system. The company is also testing the multifunction active sensor for the Navy's MQ-4C Broad Area Maritime Surveillance UAS, scheduled to make its first flight in 2012 and to join the fleet in FY16.

In other continuing development programs, the E-2D Advanced Hawkeye, the Navy's newest airborne early warning and command and control aircraft, is completing carrier suitability testing. The F-35 JSF has completed static structural testing, and flight tests continue with all three variants: the Air Force F-35A CTOL, Marine Corps F-35B STOVL, and Navy F-35C carrier variant. The F-35C completed jet blast deflector testing to validate its compatibility aboard an aircraft carrier, and the F-35B has begun testing at sea aboard the USS Wasp. The first Boeing P-8I for India's navy completed its first flight.

The Air Force awarded Boeing the contract to develop its next-generation aerial-refueling tanker, the KC-46A, based on the 767-200 platform.

The commercial aircraft segment saw several major accomplishments. Boeing certified the first all-composite commercial transport, the 787-8 Dreamliner, followed by its first delivery to launch customer ANA. Just weeks before, Boeing's largest ever airplane, the 747-8 Freighter, was granted certification for entry into service. The passenger version, the 747-8 Intercontinental, had its first flight, and flight testing continues.

Joining Bombardier's CSeries already in development in the narrowbody commercial transport segment, Airbus launched its reengined A320neo, with the choice of either Pratt & Whitney PW1100G or CFM International LEAP-X powerplants. Boeing later announced development of its 737 MAX, using CFM LEAP-1B engines.

In the midsize business jet segment, Gulfstream's ultra-long-range G650 completed several flight testing milestones en route to its type certification this year.

The field of electric and hybrid electric airplanes continues to grow. EADS introduced a series-hybrid motor glider. The Taurus G4, a four-seat all-electric testbed developed by Pipistrel and Penn State, flew. These aircraft participated in the CAFE Foundation Green Flight Challenge. Pascal Chretien piloted an all-electric helicopter for 2 min 10 sec on the first flight of any such vehicle.

Significant aircraft development studies progressed. NASA's Environmentally Responsible Aviation project is supporting technology developments to reduce fuel consumption, emissions, and noise.

by **Dyna Benchergui, Charlie Svoboda,** and **Michael Drake**

# Balloon systems

This has been a very active year for the ballooning community. Researchers from government, industry, and academia continued developing novel and ever more capable balloons, deploying them from Antarctica to the Arctic and from numerous locations in between.

The NASA Balloon Program continued to support science users on the cutting edge of high-energy physics, space science, and cosmology. Personnel from NASA's Columbia Scientific Balloon Facility conducted flights from Antarctica, Australia, Sweden, Texas, and New Mexico, with mission and safety oversight from NASA's Wallops Flight Facility. Several important technology development efforts met with success. The enhanced rotator, which provides course payload pointing to ±1 deg, was flown three times this year. The Wallops arc-second pointer was test flown during the fall activities at Fort Sumner, New Mexico, to demonstrate that balloon-borne telescopes could be pointed at inertial targets with arc-second accuracy.

In early January, the Balloon Program also launched a 422,400-$m^3$ Super Pressure Balloon (SPB) on a test flight from McMurdo Station, Antarctica. With a lift capacity of 1,800 kg, the balloon circumnavigated the continent at an altitude of 33 km in just over 22 days. The balloon deployed and performed flawlessly, maintaining near-constant-pressure altitude (±200 m), without any detectible helium loss during flight. The SPB was terminated on command to allow recovery of the payload and portions of the balloon during the campaign. The mission was a resounding success.

*The 11th Marine Expeditionary Unit launches Space Data's SkySat communication balloon from the deck of the USS Makin Island. Official USMC photo by Cpl. Tommy Huynh.*

Aerostar continued to support the program through the design and production of heavy-lift stratospheric balloons. This work included pushing the boundaries of design and fabrication techniques in support of the SPB project. After the record-setting SPB flight this year, production is now under way on a larger, 510,000-$m^3$ SPB envelope.

At the other end of the spectrum, Aerostar is also continuing to develop its small balloon flight operations. By providing customers with balloons, communications, control systems, and optional flight services, this program aims to provide new low-cost access to the stratosphere for customers with lightweight payloads.

Space Data's new balloon-based communications system, Lofted Comms, made its first contributions to combat operations. Marines from the 26th Marine Expeditionary Unit attached to Battalion Landing Team 3/8 used the system to support counterinsurgency operations in Helmand province, Afghanistan. This spring, the same unit launched Space Data's communications balloons from the USS Kearsarge to relay messages to AV-8B Harrier jump jets flying strike missions over Libya.

At Smith College, researchers continued to develop the world's smallest altitude-controlled long-duration balloons. These controlled meteorological (CMET) balloons have less mass than standard weather balloons but can communicate from anywhere on Earth via satellite, perform continuous soundings up to 5 km altitude, and remain airborne for periods of days to weeks in the absence of precipitation. This year, CMET balloons were flown in scientific studies in the Arctic and over the Amazon.

JPL, Caltech, and Near Space performed a coordinated set of cryogenic and room-temperature experiments on small-scale Titan Montgolfiere (hot air) balloons and used the data to validate a turbulent flow CFD model. The experimental data set includes infrared images of balloon testing at room temperature that provided detailed temperature distributions. This work is part of the ongoing effort to bring Titan balloon technology to maturity for possible use in a future planetary mission.

Balloon systems continue to provide low-cost, fast-turnaround, flexible, and innovative solutions to the military, planetary science, atmospheric studies, commercial applications, and accessible fundamental space science. 

by the **AIAA Balloon Systems Technical Committee**

# Flight testing

After 30 years of space missions, the space shuttle completed its final flight when Atlantis rolled to a stop at the Kennedy Space Center on July 21. The shuttle program had flown 355 individuals from 16 different countries, and logged more than 1,330 days in space.

In the postshuttle era, the U.S. plans to rely heavily on commercial capabilities for access to LEO. On December 8, 2010, SpaceX became the first private company to put a vehicle in orbit and successfully recover it. Commercial suborbital spaceflight testing also made progress when the Virgin Galactic SpaceShipTwo had its first feathered flight test on May 4. The test verified the unique shuttlecock-type configuration used for descent from space, with a flight performed from 51,500 ft after the vehicle's release from the WhiteKnightTwo carrier aircraft.

*After its release from the B-52 carrier, the X-51 Waverider was boosted to Mach 5, but it did not accelerate to full power.*

Commercial aviation flight testing included certification of Boeing's 787 Dreamliner on August 26 after it had accumulated 5,021 hr of flight time during 1,768 flights, with the use of seven airframes. Boeing completed tests on the 747-8F, a stretched and updated version of the B-747-400F, resulting in certification on August 19.

Several general aviation companies have been developing new models. HondaJet began testing its first production-conforming prototype last December and has demonstrated performance beyond its speed commitment and flight at the maximum operating altitude of 43,000 ft. Gulfstream has been very active in certification flight testing of the G250, with over 400 total flights and 1,150 test hours. Flight tests of the G650 have resumed after a mishap resulted in the death of its four-member test crew. This tragedy underscores the hazards inherent in flight test even when conducted by skilled and diligent professional teams. Lessons from mishaps are shared within the test community and ultimately enable the fielding of safer, more reliable aircraft.

In military aviation, there were several milestones in the flight testing of the F-35 JSF. These included its 1,000th test flight, and jet blast deflector testing to ensure compatibility with carrier operations. To date, there have been more than 122 vertical landings conducted; the F-35A (conventional takeoff and landing) jets have flown over 250 flights, the F-35Bs (short takeoff and landing) have flown more than 187, and the F-35Cs (carrier) more than 81.

The Northrop Grumman X-47B, a UAS developed for aircraft carrier use, conducted a 29-min first flight on February 4. The stealthy, tailless demonstrator is a step toward the long-held Navy goal of marrying persistent, autonomous unmanned intelligence and strike aircraft with the reach of its fleet of aircraft carriers. The Boeing-financed Phantom Ray, a stealthy fighter-sized UAS intended to be used as a testbed for advanced technologies, arrived at Edwards AFB atop a NASA shuttle carrier aircraft (a modified B-747) and had its first flight on April 17.

Two hypersonic test flights took place, and both experienced difficulties that highlighted the technical challenges of flying in that high-speed and high-temperature environment. The Air Force X-51A Waverider flew on June 13. After being released from a B-52H carrier aircraft, the X-51A was boosted successfully to just over Mach 5, and the scramjet engine lit using ethylene but did not accelerate to full power using hydrocarbon fuel when it transitioned to JP7 fuel operation. On August 11, DARPA's second flight of the Falcon Hypersonic Technology Vehicle 2 was an attempt to fly the fastest aircraft ever flown. The craft was successfully inserted into the desired trajectory by a Minotaur IV rocket, and then demonstrated stable flight at Mach 20 for nearly 3 min before an anomaly resulted in loss of signals from the vehicle. Data were collected with a wide array of assets to help develop a better understanding of the nearly uncharted aerodynamics and conditions in that flight environment.

by **Jay Brandon**

# General aviation

General aviation deliveries continued to decline in the first half of this year. Total shipments fell 16% over the same period last year, for a total of 791 units. The year's largest decrease was in business jets, with only 261 units shipped, a decline of 27% over last year. This reduction in high-end sales also caused a 22% drop in total billings compared to the first half of 2010.

While Bombardier and Gulfstream continue to ship primarily their larger model jets, Cessna did the most business with its smallest, the Citation Mustang light jet. Honda, meanwhile, is actively pursuing this market with the HondaJet, several of which are now flying in the production configuration. The model has achieved its speed goal of 425 kt at 30,000 ft and a maximum operating altitude of 43,000 ft. Honda plans to begin production next year at its new plant in Greensboro, North Carolina.

Piston aircraft decreased the least, dropping by 9% to 387 aircraft. Cessna actually shipped more piston aircraft than in the same period last year, a rise due largely to full production of the new 162 Skycatcher model. With 61 delivered in the first six months of the year, Cessna becomes the largest, and only major, U.S. manufacturer of light sport aircraft (LSA), since Piper is out of this market.

As dramatically as Piper announced adoption of the Czech SportCruiser and renamed it PiperSport in January 2010, this January it dropped the affiliation. The move supposedly allows Piper to devote more of its resources to developing its jet, the Altaire, expected to fly next year. The SportCruiser is still made under its original name in the Czech Republic and accounted for the third largest LSA delivery in the first half of the year.

Overall, the LSA market remained fairly stable in this period, with deliveries about the same as last year. Following Cessna, Cubcrafters had the second highest number of shipments, and Flight Design had the fourth highest, although still remaining the leading LSA market shareholder with a total of 333 aircraft since the CT was approved in 2005.

Flight Design introduced a four-place airplane this year, the C4, and displayed a mockup at the major air shows. Tecnam, meanwhile, has a flying version of its entry into the four-place market, the P2010. Both of these aircraft have impressive performance on 180 hp and are expected to sell for well under $300,000. Tecnam also announced the development of an 11-seat regional airliner, the P2012 Traveler. This prolific developer continues to deliver five different models of LSA.

*Icon Aircraft received sufficient funding to complete development of the innovative A5 amphibian and expects to start production next year.*

Cirrus has been purchased by a Chinese company, but reports that all production will remain in the U.S. The infusion of capital will allow Cirrus to put more effort into new-model development, including continued work on the Vision Jet. Cirrus also received an order of 25 SR20s from the Air Force Academy; these are to be designated T-53A trainers.

In June, Icon Aircraft received $25 million in funding and expects to complete development of the A5 by the end of the year. This innovative light sport amphibian, which attracts attention wherever it is displayed, now has over 600 orders, with production expected to begin next year.

With the declining availability and high cost of production aircraft, interest in homebuilt airplanes seems to be increasing. Last year, a total of 941 homebuilts were added to the registry, more than the total number of factory-built piston-powered aircraft shipped all year. Unlike the light sport planes that began this movement, current kit plane models include many high-performance, comfortable traveling aircraft. More than 32,000 amateur-built planes are now certificated.

by **Hubert C. 'Skip' Smith**

# Lighter-than-air systems

Northrop Grumman continued to work toward delivering the first of three LEMV (long-endurance multiintelligence vehicle) airships to the Army before year's end. The 300-ft-long envelope, built by ILC Dover, was partially inflated in June. The LEMV is a hybrid aircraft designed to generate 40% of its lift using aerodynamic forces. Delivery will be followed by deployment to Afghanistan.

The Air Force has awarded a contract to Mav6 LLC for a nonrigid airship named Blue Devil 2, which would provide surveillance similar to LEMV's mission. TCOM LP built the 1.4 million-ft³ envelope. The flight control system, vehicle control system, and radios will be provided by Rockwell Collins. The airship is designed to operate at 20,000 ft altitude for 3-5 days. It features a supercomputer to handle the vast amount of information collected by listening devices, video cameras, communication relays, and a wide-area surveillance system.

*The envelope of the Blue Devil airship is inflated with air.*

Lockheed Martin, using the technology developed from its P-791 hybrid airship, plans to build a larger 'Sky Tug' under an $86.2-million contract from Aviation Capital Enterprises in Canada. The 370-ft-long airship will use a three-lobe envelope and will carry part of its lift dynamically. It will carry a payload of 20 tons. The first airship will be a demonstration and development vehicle; a second will be used for certification in late 2012.

Development of the Skyhook, a heavy-lift hybrid by Boeing, has been halted for lack of funding.

by **Norman Mayer**

Goodyear Tire and Rubber plans to replace its present fleet of three nonrigids with Zeppelin NT07-101 semirigid airships. The German NT07s offer several improvements over the older Goodyear type. Components for the airships will be fabricated by Zeppelin Luftschifftechnik in Germany. They will be assembled at Goodyear's Wingfoot Lake facilities in Ohio beginning in 2013 and finishing in 2016. Each NT07 costs about $21 million. Goodyear also leased two A60+ nonrigids from Lightship Europe. These 70,000-ft³ airships, manufactured by American Blimp, will tour the U.K. and European countries.

Zeppelin is rebuilding its number 2 NT07 airship, which was repurchased from Nippon Aircraft after Nippon's business failure. The craft will incorporate recent improvements and will be ready in April 2012 for science flights over Italy and northern European countries. In August German Zeppelin-Reederei, the operational subsidiary of Zeppelin, completed 10 years of passenger service. Over 117,500 passengers have been flown.

Airship Ventures Zeppelin NT07 flew to the U.S. east coast and returned to California during the summer months. It visited 23 cities.

The high-altitude HALE-D airship built by Lockheed Martin was launched from its base in Akron, Ohio, on July 27. This was an initial attempt to reach 60,000 ft altitude. The flight was terminated after reaching 32,000 ft because of an anomaly, and the airship was damaged during the recovery.

The World Surveillance Group (previously Sanswire) completed the initial U.S.-based test flights of its STS-111 unmanned air vehicle, now called Argus One, at the Easton, Maryland, airport. The multisegmented nonrigid was flown at the Army proving ground facility in Yuma, Arizona.

Hybrid Air Vehicles in Cranfield, England, has signed an agreement with Discovery Air in Canada to develop an airship capable of carrying a payload of 50 tons. It would operate in remote Canadian regions exploring oil and gas mine resources.

Buoyant Aircraft Systems International in Manitoba, Canada, has developed a single-seat 80-ft nonrigid to be used as a research model to test cold-weather cargo exchange and other ideas. A hangar has also been built.

# V/STOL aircraft systems

*Eurocopter's X3 hybrid helicopter achieved an airspeed of 232 kt on May 12.*

From the start of the year, program and government officials overseeing the development of the F-35B short takeoff/vertical landing (STOVL) variant had one major milestone on their radar—ship testing of the aircraft on board the USS Wasp.

During Developmental Test 1, test pilots would verify the F-35B's basic performance and handling qualities in a flight envelope that approximates that used by fleet pilots during carrier qualification flights.

But before the F-35B could take to the seas, it had to prove itself worthy in the skies over NAS Patuxent River, Maryland. With that goal in mind, the F-35B team laid out an aggressive flight test plan to ensure that the jet was ready to take off and land from the USS Wasp.

Preparing for shipboard testing would be a journey in itself. By April, the aircraft had already completed the requisite number of vertical landings to qualify for shipboard testing. In addition, the B model had logged more flights than either of the other two variants of the F-35 and was significantly ahead of planned test point completion performance.

The system development and demonstration (SDD) F-35 fleet at Patuxent River got reinforcements in July with the arrival of test aircraft BF-5. Lockheed Martin test pilot Bill Gigliotti flew the STOVL for the 3.5-hr flight from NAS Fort Worth Joint Reserve Base in Texas.

Later that same month, Gen. James F. Amos, Marine Corps commandant, highlighted the F-35B's test flight performance, inviting more than 30 members of the national media to view the STOVL jet in action. Marine Corps pilot Lt. Col. Fred Schenk executed a short takeoff, 60-kt fly-by low-level pass, and hover. He then rotated the aircraft into the wind and performed a flawless vertical landing from 150 ft above the runway.

After the flight, Lt. Col. Schenk told reporters, "I executed all the maneuvers we fly here for flight test on a daily basis. It was just another day at the office."

By mid-September, the aircraft had achieved an impressive 143 vertical landings this year, compared to the 10 accomplished in all of 2010. So far in 2011, STOVL pilots had successfully completed 223 test flights—nearly matching the total number of all previous F-35B test flights. These flights racked up 1,671 test points and more than 266 flight hours, and along the way completed 265 short takeoffs.

Before rendezvousing with the USS WASP, the STOVL underwent testing at the Naval Electromagnetic Radiation Facility that simulates the shipboard electromagnetic environment to identify any potential issues with the aircraft.

*The first F-35B vertical landing aboard the USS WASP occurred on October 3 with USMC pilot Lt. Col. Fred Schenk at the controls.*

In other breakthroughs this year, the Sikorsky X2 compound helicopter, which set an unofficial speed record of 253 kt in level flight, received the prestigious Collier Trophy on May 5. It made its 23rd and final flight on June 23, accruing 22 hr in the air. On another front, Eurocopter's X3 hybrid helicopter achieved an airspeed of 232 kt on May 12.

by **E.R. Wood**

## Legal aspects

Domestic U.S. and international law and policy continue to have significant impacts on aerospace. For example, domestically, FCC approvals for a new satellite-based broadband service by Lightsquared, a mobile satellite service, have been questioned by the Pentagon and Dept. of Transportation. They express worries that the service will increase the potential for interference to GPS receivers. Congressional critics complain that the White House has been pressuring DOD and others to withdraw the objections, and change their testimony, perhaps because several large campaign contributors are associated with Lightsquared. More globally, the International Telecommunications Union still struggles over what to do with Iran, which has allegedly been jamming satellite broadcasts.

***Export control processes make it difficult for U.S. firms to share information even with their own international subsidiaries. This includes technologies needed to win contracts or to explore collaboration with firms in allied nations.***

DOD's Defense Contract Management Agency has rejected a United Launch Alliance request for recovery of $271 million in costs related to the Delta IV rocket program. Boeing, ULA, and the Air Force have been involved in a separate case over pricing for three Delta IV missions. State Dept. efforts involve space survivability, orbital debris mitigation, and discussing best practice guidelines for space activities. Insurance policies responsive to the risks of on-orbit collisions may be needed to respond to this growing threat and to the resulting prospects for litigation.

Export control headaches continue, and the AIAA has offered expert congressional testimony on the topic. The hope is that new legislation and an ongoing presidentially directed review will provide relief from export laws and regulations that hamper international trade and scientific cooperation. As a first step, the administration will likely propose regulatory simplification and administrative realignments.

Export control processes make it difficult for U.S. firms to share information even with their own international subsidiaries. This includes technologies needed to win contracts or to explore collaboration with firms in allied nations. This can shut U.S. firms out of competition for foreign aerospace programs at very early stages. The commercial satellite market share of U.S. satellite manufacturers has dropped since major changes were made to the Arms Export Control Act (AECA) and its affiliated International Traffic in Arms Regulations (ITAR) in the late 1990s. Those amendments were prompted by a satellite manufacturer sharing technical data with China about the 1995 failure of a Long March 2E rocket carrying the APSTAR II spacecraft and the 1996 failed launch of a Long March 3B carrying an INTELSAT 708 spacecraft, and by other matters concerning its business activities in China. The changes had an immediate effect on work in the area by many U.S. aerospace entities.

The introduction in recent years of 'ITAR-free' satellites by the European manufacturer Thales Alenia Space has generated a sense of urgency about the problem. The satellites, which are said to contain no U.S.-built components, are claimed by proponents to be freely exportable to China for launch there. Such ITAR-free marketing strategies pose a competitive threat to the U.S. satellite industry.

The complex, bureaucratic U.S. export-control regimes are divided among three agencies: the Commerce Dept., the State Dept., and the Dept. of the Treasury. Control by multiple agencies, with different agendas, has high associated costs. Overlapping jurisdictions create confusion as to where specific items fall, even to administrators in the agencies. The threat of criminal prosecution, jail time, and heavy fines exacerbates this fear. Previous efforts to change the laws have foundered amid congressional opposition stirred up by anxieties over the Chinese theft of technologies used in missiles, satellites, and weapons of mass destruction.

Particularly troubling is the concept of a 'deemed export,' which means the release of technical information to a foreign national, even in the U.S. Deemed exports could involve the unapproved disclosure of controlled information at an industry or academic conference, or a professor lecturing to a class that includes foreign nationals. Fears over prosecution have led academics to self-censor instruction, particularly in the area of satellite technologies.

by **James D. Rendleman**

# Society and aerospace technology

On September 15, 2011, a small NASA team of two medical doctors, a psychologist, and an engineer accepted one of just nine annual Samuel J. Heyman Service to America Medals (also known as 'Sammies') presented nationwide. The team, comprising Michael Duncan, J.D. Polk, Al Holland, and Clint Cragg, was awarded the National Security and International Affairs Medal for its ability to bring decades of U.S. expertise in spaceflight to the problem of rescuing 33 miners trapped some 2,000 ft under the Chilean desert.

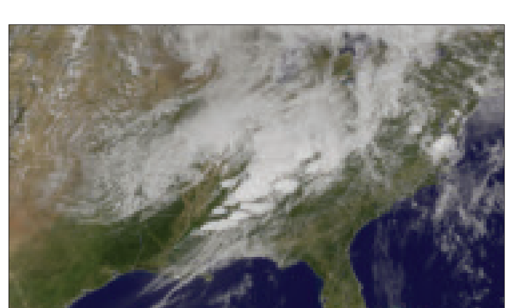
This was not the only example of the aerospace industry's ability to assist society and project goodwill across the globe. Aerospace professionals and the technology the industry provides assisted in furnishing a ready stream of data to aid in predicting or responding to major natural disasters. These included the Japanese earthquake and tsunami, the Australian floods, and major tornado outbreaks in Alabama and Missouri.

The industry has also enabled bold new efforts such as the Internet-based Satellite Sentinel Project, which uses high-resolution satellite imagery to monitor and make public within one or two days possible human rights violation activity along the tense border between northern and southern Sudan (or, as of July, Sudan and the new nation of South Sudan). In addition, the international space station continues to operate as a national laboratory with capabilities available nowhere on Earth. Experiments and research such as the recombinant attenuated salmonella vaccine investigation, launched on STS-135, are always on the agenda.

NASA's recently formed Office of the Chief Technologist released the annual issue of *Spinoff*, highlighting 49 benefits to society spun off from aerospace technologies generated by programs such as the ISS, telescope and deep space exploration, satellite projects, space transportation, astronaut life support, and aeronautics. These benefits range from health and medicine (stronger hip implants, cranial pressure monitoring techniques), to transportation (air traffic management, helicopter noise reduction), public safety (icing detection, parachutes for small airplanes), consumer goods (extreme temperature insulation, plant-growth-targeted LEDs), environmental resources (real-time water quality analysis, groundwater remediation), computer technology (fluid dynamics modeling, verification tools for online shopping and banking), and industrial productivity (lightweight composite materials, deformable mirrors).

This year also brought the retirement of the space shuttle fleet and with it a decision on the final museum locations for the remaining orbiters. Discovery, the oldest and world's most flown spacecraft, will be displayed by the Smithsonian's National Air and Space Museum at its Udvar-Hazy Center located near the Washington Dulles International Airport. Endeavour will be given to the California Science Center in Los Angeles. Atlantis will remain in Florida at the Kennedy Space Center Visitor Complex. And Enterprise, its name a direct example of the impact that society can have on aerospace technology, will be transferred to the Intrepid Sea, Air and Space Museum in New York City. These orbiters will no doubt help inspire the next generation of engineers to push the envelope of possibilities in aeronautics and space efforts.

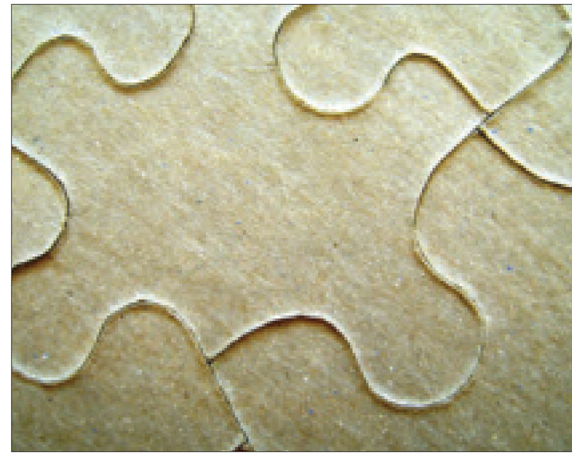
With the shuttle retired and no domestic capability for launching astronauts to orbit, a question many are asking is simply, 'What's next?' Some may even wonder, 'Will we leave Earth orbit in my lifetime?' It may be a surprise to many that the latter is already taking place—albeit in simulated form. As part of an elaborate $15-million experiment called Mars500, a diverse team with members from Russia, China, and Europe volunteered to spend 520 days isolated from the rest of the world in a 550-m³ facility in Moscow on a simulated mission to Mars. With 20-min communication delays, the crew had to be completely self-reliant. This is just one example of how the aerospace industry can benefit from interactions with the sociology and psychology communities. The crew 'returned to Earth' on November 4.



*GOES observed an Alabama tornado outbreak storm system, on April 27, 2011. Credit: NASA.*

by **Jarret Lafleur** and **Bradley Steinfeldt**

# Systems engineering



*The overall system includes not only the individual subsystems but also their interfaces.*

By definition, systems engineering is an interdisciplinary approach to designing and developing complex systems for purposes of creating successful products. The process entails defining the system architecture, which is an aggregation of decomposed system components interacting to produce a successful system. The overall system includes not only the individual subsystems, each of which performs specific functions, but also their interfaces. The system requirements need to reflect the performance of both elements.

Despite the fact that organizations employ systems engineering processes, failures still occur. Many times the failures tend to be at the boundaries and interfaces, because more attention is paid to the decomposed systems than to the interactions and integration among the subsystems. It is typically taken for granted that systems engineering will take the interfaces into account as well as the performance of the individual subsystems themselves. However, these interfaces often do not address the dynamic interactions between subsystems.

Further exacerbating these dynamic interactions is the adoption of new requirements or changes to existing requirements once development has begun. When requirement changes occur, we frequently accept them as a response to customer needs, without fully understanding the impact of these changes. This lack of understanding is due to the unclear definition of the interfaces and their interactions—the secondary effects. The occurrences of these secondary effects can result in increased cost growth and schedule slippage.

To improve understanding of the subsystem interfaces, systems engineering should focus on the context and interactions of the subsystems rather than on the structure of these subsystems. The first step toward addressing this problem is to define the overall strategy or objective of the system being produced. For example, what is the expectation on the part of the customer for the final product—what does the customer want? During the requirements generation process and systems formalism, we tend to lose sight of the objective. Once the product objective is understood, the program should then focus on how to organize the team given the environment in which the work is to be performed.

In addition to the resources needed to develop the systems that make up the final product, the organization should include resources responsible for systems integration. Successfully integrating the product requires a keen understanding of the interfaces and the interrelationships associated with the various components. Interface problems may involve user operability of the system as well as process changes leading to technical changes.

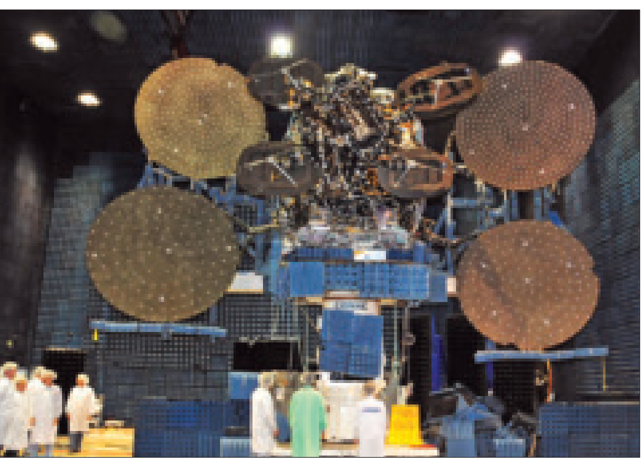
The systems engineering community, which has traditionally focused on technology readiness levels and manufacturing readiness levels, is now moving toward active use of integration readiness levels (IRLs) or systems readiness levels (SRLs). IRLs and SRLs are tools that system integrators use to determine if the interface requirements have been implemented sufficiently so that the systems are ready to be integrated. This move toward IRLs and SRLs should improve the situation, but will require time for trial and error to eventually produce significant improvement in program results.

To reduce the number of system failures, more attention must be paid to defining the interface problems among the various subsystems, including the interactions of those subsystems and their associated interfaces. To do this, the program needs to define the product objective. The program then must establish an organization that is structured in such a way that it will address system interfaces and interactions routinely as it develops the overall integrated system, ensuring that nothing is overlooked in the complete system integration.

by **Tsutsumi Sophia Bright**

## Communications systems

Satellite industry activity is down from the last several years, with about 20 commercial awards projected for the year and the same number of launches. Through October, 14 contracts were awarded; expectations are that many planned projects will be announced before year's end or early 2012. Space Systems/Loral (SS/L) and Astrium have each been awarded four satellite contracts and there have been two awards each to MELCO and Orbital, one for ISS-Reshetnev (Kazsat 3, with payload built by Thales), one to CAST, and none to Lockheed, Boeing, or Thales.



*ViaSat-1 was successfully launched in October.*

The launch services business continues to be split between ILS and Arianespace, with Sea Launch returning to service with the launch of Atlantic Bird 7 in late September. The ILS Proton launch manifest suffered dual setbacks with delays in the delivery of SS/L spacecraft after a solar array deployment anomaly on Telesat's Telstar 14R, and then the failure of the Breeze M upper stage on the Express AM4 launch. Proton is attempting to make up the delays by launching approximately every 20 days after their September return to flight. SpaceX revealed that there was an engine anomaly on last year's maiden Falcon 9 launch.

In the broadband market, Eutelsat's Ka-Sat, with a capacity of about 70 Gbps, entered service, and ViaSat-1, the first broadband satellite with a capacity of 140 Gbps, was launched in October. More broadband satellite procurements are expected, for service to Africa, Europe, North and South America, the Middle East, South Asia, and Australia.

In the direct broadcast service market, Intelsat ordered two 20-kW satellites from SS/L, both of which are for DIRECTV Latin America, and SES launched QuetzSat for use by Dish Mexico in September. In addition to demand in Latin America, pay-TV satellite platforms are also on the increase throughout the Asia-Pacific region, especially in Southeast Asia. In North America, AsiaSat announced its intention to procure two satellites by year's end.

The Middle East continues as a growth market, with Arabsat averaging more than one satellite launch per year over the past five years—Yahsat's first satellite entering service earlier this year and their second planned for launch in 2012, and Qatar Satellite joining with Eutelsat on the EB2A/Es'Hail satellite. Numerous procurements are planned by both incumbents and new entrants in this region.

Interest in hosting government payloads on commercial satellites continues to grow, and organizations dedicated to exploring issues and opportunities were established by both an alliance of industry organizations and by the USAF SMC. The CHIRP hosted payload on SES-2 was launched in September. By hosting this missile-warning payload on a commercial satellite, the SMC will be able to demonstrate the performance of a next-generation infrared technology for a fraction of the cost of a dedicated military satellite.

The MilSatCom Directorate at the USAF SMC conducted a series of studies to explore industry's ability to support military communications needs. The results demonstrated that industry can provide cost savings and enhanced resilience to MilSatCom architectures in multiple ways.

NASA's Office of Chief Technologist selected three technology demonstration missions, two to be hosted on commercial satellites, and announced two additional acquisitions that will include hosting on commercial satellites as an access-to-space option.

For the U.S. government, the NRO successfully launched six satellites over an eight-month period, a launch tempo not seen by them in 25 years. Also of note was the Army's launch of several Cubesats on a Falcon 9. The Air Force launched the first SBIRS satellite and continued to use electric propulsion to orbit-raise the AEHF-1 satellite launched over a year ago, compensating for the failure of its main thruster.

In terms of policy, the White House announced a plan for restructuring and consolidating all export regulations aimed at simplifying the regulatory environment for U.S. companies and their customers. It is expected to deliver a report on technology transfer risks and how ITAR regulations for satellite technology might be reformed by the end of this year or in early 2012.

by **Christopher F. Hoeber**

# Computer systems

The typical digital gadget, powered by the latest advances in computing, is often rendered obsolete within a year. While spacecraft computing does not change that fast and has vastly different requirements, many such advances are showing up in spacecraft computing architectures. Meanwhile, international competition for the fastest supercomputer has heated up, and cyber warfare seems to have arrived.

The space plug-and-play architecture (SPA) will demonstrate its newest adaptation on the Trailblazer CubeSat early in 2012. SPA-1 is an adaptation of the low-cost I2C bus. It expands the SPA family, which already adapts SpaceWire (SPA-S) and USB (SPA-U). This year, AIAA posted SPA documents for review through its standards process.

Commercial smartphone technology is being tested in orbit. An Android-powered Nexus S phone arrived aboard the ISS and will provide the user interface for a number of experiments. PhoneSat, a CubeSat with a Google Nexus One phone in it, will be launched into orbit to demonstrate its potential as an instrument as well as an instrument controller.

Spacecraft computing power will soon be enhanced by multicore or multiprocessor designs in several ways. A multiprocessor chip uses many copies of the same core to boost performance. Mobile devices often combine different cores (such as CPU, 3D graphics renderer, and DSP) into a system-on-a-chip (SOC). Even within a core, redundant elements may exist for reliability (radiation-hardening, for example) or parallelism (DSPs) or both.

Here are some examples: Boeing is working on Maestro, a rad-hard 49-core device derived from the Tilera Tile64. Aeroflex is using LEON3FT, a fault-tolerant SPARC core, as part of an SOC. BAE Systems is producing the RADSPEED DSP, a 152-processing element rad-hard adaptation of the ClearSpeed CSX700. Between the tightly optimized extremes of SOC and DSP devices are FPGAs (field programmable gate arrays), which mix and match cores, but at the cost of chip area, performance, or power. Some FPGAs are supplemented by hard cores for SPARC, PowerPC, or other embedded processors. Others implement soft processor cores within the FPGA itself. The net effect of all these multicore or multiprocessor designs is to allow increased processing of sensor input and more spacecraft autonomy for longer missions away from Earth.

*A stock Android HTC phone can work just fine as a low-cost satellite. Here is Phonesat, mounted in a Cubesat chassis and launched with a balloon. Image courtesy NASA Ames.*

In June, Japan reclaimed the top spot on the TOP500 list of the world's fastest supercomputers. The half-built K Computer reached 8.612 petaflop/sec using 68,544 vector-enhanced SPARC64 elements built by Fujitsu. It is expected to pass 10 petaflop/sec when completed in 2012. The Chinese Tianhe-1A supercomputer reached 2.6 petaflop/sec through its use of NVIDIA GPUs. The U.S. Oak Ridge National Lab's Jaguar reached 1.75 petaflop/sec. It is a Cray XT5 supercomputer using AMD Opteron elements.

The underlying circuit technology is moving to 3D transistors, dramatically shrinking their size and power consumption. Intel is introducing them this year in all of its processors. AMD spinoff GlobalFoundries is said to be working on a 3D processor as well.

The past year made the prospects of cyber warfare impossible to ignore. In late 2010, Iranian uranium enrichment centrifuges were struck by the Stuxnet computer virus. This year, foreign government and nongovernment actors are suspected of break-ins on servers at U.S. aerospace companies and popular e-mail services. Hacker groups targeted companies they felt were treading on free speech or other freedoms. In May, DOD announced that it may treat U.S. infrastructure cyber attacks as acts of war warranting military response. Hacker groups responded with a spike in cyber vandalism to protest the policy. Meanwhile, activists and governments worldwide discovered the power of Internet-enabled social media.

During the summer, a European Internet certificate authority was compromised, breaking the chain of trust required for credit card and other online transactions and communication. All major Web browsers were affected, forcing them to issue patches for the breach.

by **Rick Kwan**

# Digital avionics

It is not surprising that our cockpits continue to grow more exotic. Indeed, more electronic 'fly by wire' is not anything new. What is new is that *all* the flight control processing, memory, software, and interfaces can now fit on a single FPGA (field-programmable gate array). This is a starting development.

*Touch screens are even making their way into the latest military fighters.*

It is very hard to keep up with what is new in digital avionics for this year, because changes are being fielded so rapidly. What is amazing is that this appears to be the year of the touch screen. Perhaps this has been brought about by the huge success of the latest iPad, or the thorough propagation of the iPhone, Droid, and the other 'smart' devices. Increasingly, people are finding it difficult to remember that their PC monitors are not touch screens. As their pervasiveness increases, look for them everywhere.

The Avidyne IFD540 touch screen includes flight management, GPS, navigation, and communications capabilities. The system is a slide-in replacement for the Garmin GNS530 and has a high-resolution display.

Garmin has introduced the new GTN series (650 and 750) to replace its 430 and 530 systems. Their touch screens can even be used to reroute the aircraft around weather systems (graphical flight planning). These new systems also have much larger displays.

Rockwell Collins has its ProLine Fusion integrated flight deck, which uses either the legacy systems for data entry (buttons, knobs, and so on) or the touch screens. This system is planned for small jets such as Embraer Legacy 500, the Bombardier Global 5000, and the Lear 85.

One design aspect that will be interesting to see is whether someone will have the foresight to triple (or more) the size of the selection buttons on the screen based on aircraft turbulence. It will be very difficult to 'touch' a ½ x ½-in. virtual button while flying through a thunderhead.

On fighter aircraft, there has been a physical bar that runs along their displays to anchor the fingers—something to hold on to while making a selection. The Garmin GTN systems have a similar 'fingerboard' to steady the hand. Voice control is another option with the Garmin GTN.

There are, of course, both benefits and drawbacks to touch screens. No doubt the flexibility is tremendous, enabling the user to touch and drag the instruments to different locations on the displays, for example.

On the other hand, what happens when pressing the button does not result in what the pilot was expecting? Or what if a single embedded device fails, and the result is a cascading event that takes out much or all of the display? Or, like the failure mode of a thumb drive, there is a complete loss, without so much as a 'blue screen of death.' What does the pilot do? The answers are not yet clear.

Electronic flight bags (EFBs) are another great place for the touch screen. The iPad is now the latest EFB, complete with the Mobile Flight Deck app that includes the Jeppesen charts for en route, area, approach, and airports. They also allow flight planning.

So, is this all a good thing? Absolutely. But a vital question remains: What do we do if we forget our charger—again?

by **Art Tank**

# Intelligent systems

From intelligently directing robots on the ISS via smartphones to advances in verification for safety-critical systems, 2011 brought exciting developments across the spectrum of intelligent systems.

On the ISS, the SPHERES (synchronized position hold, engage, reorient, experimental satellites), originally developed by MIT, were equipped with smartphones running the Android platform, delivered by the last shuttle mission. By equipping them with smartphones, the NASA Ames Intelligent Robotics Group enables these self-propelled, volleyball-sized satellites to become capable robots, able to take pictures, record video, perform complex calculations, and transfer data in real time to the ISS and Mission Control. NASA will use the upgraded SPHERES to conduct visual inspections and numerous other tests (http://googleblog.blogspot. com/2011/09/android-in-spaaaace-part-2.html).

Researchers at JPL won the 2011 NASA Software of the Year Award for AEGIS (autonomous exploration for gathering increased science), which pushed the boundary for automated targeting and data collection onboard the Mars Exploration Rover Opportunity. AEGIS uses onboard data analysis to select rock targets in rover image data. If targets are found that match scientist-specified criteria, new targeted observations are automatically acquired without requiring interaction with human operators. AEGIS allows the rover to autonomously gather high-quality remote sensing data on scientifically interesting rock targets as soon as the rover reaches a new area.

Meanwhile, in aeronautics, the Samarai micro air vehicle achieved completely autonomous flights with all sensing, guidance, navigation, and control done onboard the wholly rotating MAV—a first for rotating mono-wing air vehicles. Developed by Lockheed Martin Advanced Technology Laboratories, Samarai weighs 7 oz and consists of a single 12-in.-radius wing powered by an electric motor/propeller at the tip and a servo-driven trailing-edge flap as the sole control surface. Despite this control surface limitation, its innovative MALCOLM (multi-application control of MAVs) algorithms achieved full authority control of the MAV in all degrees of freedom by automatically translating mission inputs into specific control objectives and intelligently allocating control between flap and throttle to preserve flap authority for maneuvering.

Responding to the need to prevent airspeed system failures like those contributing to the 2009 Air France Flight 447 disaster in which 228 people died, Galois and the National Institute of Aerospace developed a novel language and compiler called Copilot, for use in monitoring avionics software. Copilot is open source and generates hard real-time embedded C code from high-level behavioral specifications, providing in-flight software health management. With NASA Langley, the team tested its monitoring system on an airspeed system for a subscale unpiloted aircraft. Copilot monitors detected both software and physical faults injected into the system while meeting timing constraints (http://leepike.github.com/Copilot/).

*A Copilot compiler monitors an airspeed system for a subscale UAV.*

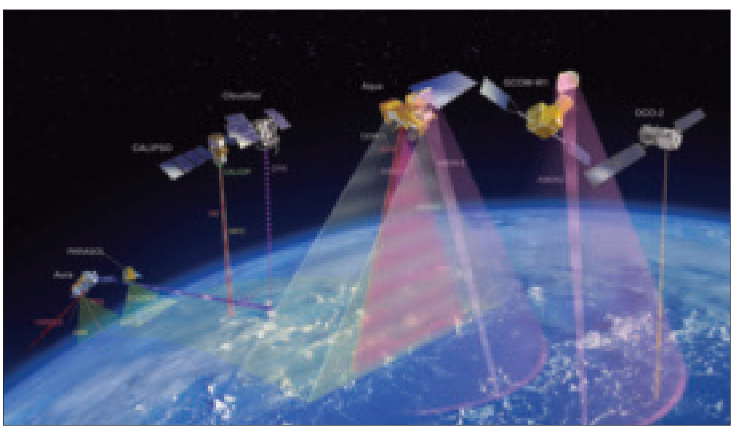
The Temporal Logic Planning Toolbox, TuLiP (http://Tu-LiP-control.sf.net), enables formal, automated synthesis of protocol-based control software for intelligent systems. To overcome the difficulty inherent in verifying complex intelligent systems after they are built, the toolbox is based on a shift from the traditional 'design and verify' approach for establishing trust to 'specify and synthesize.' Developers at Caltech conducted case studies including autonomous navigation and design of reactive, dynamic resource management logic for vehicle management systems.

Rice, Drexel, and the Universities of Michigan and Maryland furthered the reach of intelligent systems by designing a prosthetic arm amputees can control directly with their brains; the device also allows them to feel what they touch. Through a $1.2-million grant from the National Science Foundation's Human-Centered Computing program, the project aims to tie together noninvasive neural decoding, direct brain control, and tactile sensory feedback into a single device. By providing sensory feedback in a natural way, this technology may also allow astronauts to see and feel through a robotic arm working outside the ISS from a virtual reality station inside. http://www.media.rice.edu/media/NewsBot.asp?MODE=VIEW&ID=15983&SnID=18803147o.

by **Kristin Yvonne Rozier**

# Sensor systems

This year, commercial sensors system technologies impacted areas such as safety systems, surveillance of global weather patterns, and measurement of extraterrestrial phenomena. In the military world, even in an environment of shrinking defense budgets, new technologies for electronic warfare, or cyber operations, are emerging. Together with the new weapons systems, technologies for targeting computer, network, and electronic attacks are all under development.



*A satellite constellation known as the A-Train will improve our understanding of aspects of the Earth's climate. Courtesy NASA.*

In the commercial world, Honeywell Aerospace and Gulfstream Aerospace are developing enhanced vision systems (EVS) and synthetic vision systems (SVS) using overlaid infrared-sensor systems under contract from NASA. EVS, integrated to the cockpit head-up display, allows pilots to see the runway in low-visibility conditions. SVS provides better situational awareness of obstacles and terrain.

In military cockpit sensor system technology, the Automatic Ground Collision Avoidance System (Auto-GCAS), led by Lockheed Martin Aeronautics and the Air Force Research Laboratory (AFRL), is a system that predicts a ground collision. It then performs an automatic avoidance maneuver in order to save the pilot's life, even if the pilot has lost consciousness because of *g*-induced maneuvers, has become disoriented, or has lost situation awareness. Auto-GCAS performs the automatic recovery maneuver between the point when the pilot normally gets the warning alert and the point of nonrecovery.

Another new military sensor system technology is the latest Israel Aerospace Industries Elta EL/L-8265 radar-warning receiver. This new receiver provides not only the direction of the threat, but also the range, which is unique in this type of technology. Another feature is its single-ship geolocation capability. The range of the threat is generated by Doppler radar beam-sharpening technology. Designed to provide 360 deg of wide frequency band coverage, the system weighs only 11.5 kg, so the technology is attractive for both unmanned and manned platforms.

NASA has built a small, low-cost spacecraft called the Fast, Affordable Science and Technology Satellite and AFRL had an innovative experiment called the Threat Detection System. Together they created a partnership "to build something that will fly in space for a short time frame and for a relatively thrifty amount of money."

In the area of commercial space radar systems, European and North American companies are continually advancing these technologies. Examples include Germany's TerraSAR-X and Tandem-X, which are 1-m-resolution commercial X-band imaging satellites. Other examples are Canada's Radarsat 1 and 2 and the Italian CosmoSkyMed constellations. All of these systems contribute to the needs of defense, business, and environmental protection. A key example was last year's BP oil spill in the Gulf of Mexico, in which Radarsat 1 and 2 provided situational awareness of the disaster.

NASA launched the Juno mission to Jupiter in August, picking up where the Galileo mission left off in September 2003. Its mission builds on Galileo, allowing in-depth investigation of many of the earlier spacecraft's discoveries. Unlike Galileo, which ran on nuclear radioisotope thermoelectric generators, Juno is running on solar power, having benefited from advances in solar cell design. Its cells are 50% more efficient and radiation tolerant than the silicon cells that were available for space missions 20 years ago.

Juno has nine instruments for collecting data on Jupiter's structure and composition. These include a gravity/radio science system, a six-wavelength microwave radiometer for atmospheric sounding and composition, a vector magnetometer, plasma and energetic particle detectors, a radio/plasma wave experiment, an ultraviolet imager/spectrometer, and an infrared imager/spectrometer. Juno will orbit Jupiter's poles in order to avoid its radiation belt, a lesson learned from the Galileo mission.

by **Wei-Jen Su**
and **James Keeney**

# Software

Software is pervasive in aerospace systems, and it is critical in the implementation of required complex capabilities that go beyond those of hardware. This year the aerospace industry developed many game-changing capabilities and platforms enabled by onboard software.

From the Air Force Research Laboratory comes a military aviation success story, the development of the Automatic Ground Collision Avoidance System (Auto-GCAS). This software-based capability is designed to save lives and aircraft from the main cause of fighter and attack aircraft losses: controlled flight into terrain. The Auto-GCAS capability mixes an onboard terrain database with real-time control and navigation data to enable an aircraft to maneuver away from an impending ground collision. This new capability is being targeted for transition to F-16s, F-22s, and F-35s. Designed by Lockheed Martin, Auto-GCAS can be integrated onto these fighter platforms with only software modifications to the aircraft.

Other software aspects of Auto-GCAS include minor mission planning software changes and modifications to depot automated test equipment. On board the fighters, Auto-GCAS software is involved in system-wide integrity monitoring code, an aircraft trajectory prediction algorithm, a digital database terrain map scanning algorithm, a collision avoidance estimation routine, a flight control maneuver command coupler, a pilot interface code to provide override/blending control and mode selection, HUD system displays, and audio tone control code. According to the Air Force, only one aircraft would have to be saved by the Auto-GCAS capability to pay for the entire AFRL program.

In commercial aviation, the Boeing 787 Dreamliner achieved certification from the FAA and the European Aviation Safety Agency this year and was delivered to its first customer, All Nippon Airways of Japan. The Dreamliner is the first major commercial passenger airplane development by a U.S. company in 16 years, since the Boeing 777 went into service in 1995. The 787 development and certification included integration of software from dozens of suppliers with up to 18 million source lines of onboard software code.

The 787 onboard software is critical for functions as varied as flight control, navigation, passenger entertainment, passenger cabin lighting, dimmable window tint control, and even control of the bidet in the passenger lavatory. The flight control software allows for optimizing wing camber in flight, resulting in improved aerodynamic efficiency throughout the flight envelope. The 787 software also implements fully augmented authority in all three axes. Among other things, this enables maneuver load alleviation that has allowed the reduction of thousands of pounds of structural weight. On the lighter side, software control of the cabin LED lighting systems allows for an infinite color palette and the opportunity to paint sunrises and sunsets during long flights to help passengers fall asleep or wake up.

*Flight control software on the 787 allows for optimizing wing camber in flight.*

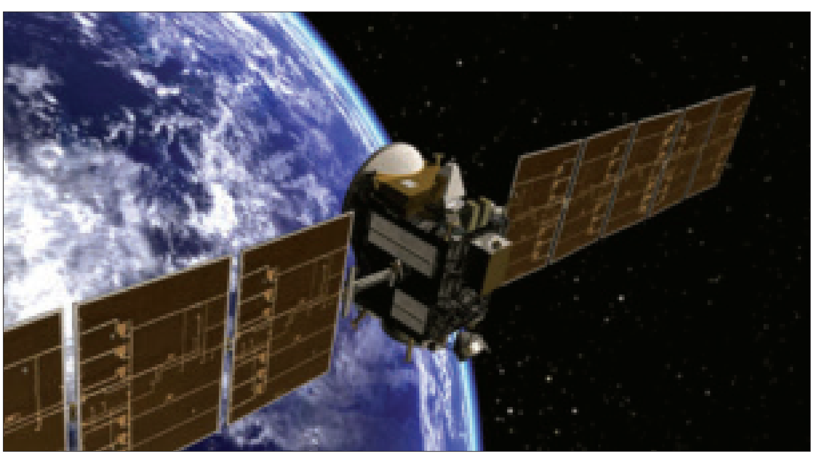
Software is also pervasive in space systems and contributes to wide-array or onboard spacecraft and spaceflight support capabilities. Examples are in this May's Rotary National Award for Space Achievement Stellar Award nominations, which include individuals and teams from Boeing, L-3 Communications, NASA Johnson, Orbital Sciences, Pratt & Whitney Rocketdyne, and the Air Force. The areas include the development of innovative system software modeling methods, simulator development, support for solar forecasting and ISS regenerative life support systems, and verification and validation methods.

From space to commercial planes to military aircraft and associated ground systems, software has played an important role in delivering advanced capabilities to customers. This is a trend that will continue.

by **Jim Paunicka**

# Aerospace power systems

This year brought significant advances in both solar and nuclear power technology and their application to complex space missions, many in harsh environments. Photovoltaic cells for space saw significant technical breakthroughs using lower mass multijunction cells with improved bandgap optimization and spectral utilization. Inverted Metamorphic cells are being demonstrated by Emcore, Spectrolab, and MicroLink Devices, some achieving efficiencies exceeding 32%, with flight-ready cells expected in the near future. Further enhancements already demonstrated in the laboratory indicate that efficiencies exceeding 37% can be realized in a few years.



*Dawn will orbit Vesta, then transfer to orbit around the dwarf planet Ceres.*

Meanwhile, the current standard triple-junction cell technology with efficiencies exceeding 29% has led to lower cost and higher reliability, while array integrators are pursuing higher power levels of tens to hundreds of kilowatts with more compact packaging to allow smaller launch vehicles, or higher capability from a single launch vehicle. Array approaches being demonstrated to satisfy up to 300 kW per mission include Ultraflex from ATK, high-power HPSA from Boeing, and the rollout ROSA from Deployable Space Systems. To improve cost and reliability, modularity and automation approaches also have been developed, such as the MOSAIC standardized module from Vanguard Space Systems.

The NASA New Frontiers mission Juno, the first solar-powered spacecraft to explore Jupiter, was launched on its five-year trip to Jupiter's polar orbit. The Lockheed Martin spacecraft is spin stabilized with three solar panel wings that span approximately 66 ft and produce 12 kW of power at 1 AU and about 420 W at Jupiter. Juno uses a highly elliptical orbit to avoid the radiation belts and keep the solar panels in sunlight continuously. Two 55-A-hr lithium-ion batteries provide energy storage for load leveling, and the power electronics are shielded in a vault to protect them from the harsh radiation environment.

The NASA Discovery Program Dawn entered orbit around the asteroid Vesta, on its way to being the first spacecraft to orbit an asteroid and then transfer to orbit around a dwarf planet, Ceres. Dawn, provided by Orbital Sciences, includes high-power 2.6-kW xenon ion thrusters producing 92 mN. The thrusters are powered by a solar array rated at 10 kW at 1 AU and delivering 1.3 kW at 3 AU at end of mission.

The Mars Science Laboratory mission, managed by JPL as part of the NASA Mars Exploration Program, was delivered for launch late this year. It includes the Curiosity rover, slated to land inside Gale crater on Mars. Curiosity is powered by the Boeing MMRTG (multimission radioisotope thermoelectric generator), which provides 2.5 kWh per day while contributing to the rover's thermal stability through waste heat recirculation.

The advanced Stirling radioisotope generator (ASRG), in development by the Dept. of Energy on behalf of NASA, has undergone extended operational testing of an engineering unit developed by Lockheed Martin, including a pair of Stirling convertors provided by Sunpower. Testing at NASA Glenn achieved over 14,000 hr of reliable operation. The ASRG uses only one-quarter of the plutonium dioxide fuel needed by radioisotope thermoelectric generators to produce a similar amount of power, thus extending the limited national supply of plutonium 238.

NASA and DOE began building a non-nuclear system-level technology demonstration unit of a fission reactor power source, comprising a reactor simulator, power conversion unit, and heat rejection system. NASA Marshall assembled the reactor simulator with electromagnetically pumped liquid metal NaK at temperatures up to 900 K. Sunpower has started assembly of the Stirling engines to prepare for future integration and test at NASA Glenn in the thermal vacuum facility. The heat rejection system will be added later for system-level demonstration by 2016.

by the **AIAA Aerospace Power Systems Technical Committee**

## Air-breathing propulsion systems integration

This year marked various important milestones and initiatives in environmentally friendly propulsion.

The second phase of the NASA/General Electric collaboration on open rotors is nearing completion with the end of aerodynamic and acoustic testing this fall in the NASA Glenn 8x6-ft Supersonic Wind Tunnel. Additional generation-2 blade designs will be tested in the early winter. NASA is also conducting systems-level analysis of the aerodynamic and acoustic character of an open rotor-based propulsion system on a modern airframe.

As part of NASA's Supersonics Program, a low-boom inlet concept was also tested in the Glenn 8x6-ft Supersonic Wind Tunnel. The inlet was designed to demonstrate a unique relaxed-compression configuration for sonic boom reduction, for a Mach-1.6 aircraft with a two-engine external pod configuration. The testing, which included passive flow control using vortex generators, was performed on two inlet configurations: a fundamental single-stream version and a dual-stream engine-bypass version. Inlet performance (stability and operability) was assessed for a wide range of mass flow rates, Mach numbers, and angles of attack.

In addition to conventional instrumentation, an internally mounted video camera pointing toward the axisymmetric centerbody allowed visualization of surface streamlines coupled with quantitative surface pressure distributions. This helped assess the impact of the novel supersonic vortex generators on the normal shock-wave and boundary-layer interaction. The subsonic diffuser included vortex generators (designed and optimized using a Design of Experiments approach) that dramatically reduced the boundary-layer shape factor at the hub-side aerodynamic interference plane, thereby minimizing local distortion. The inlet also displayed high recovery, excellent buzz margin, and high operability over a wide variety of conditions. This successful demonstration of the relaxed-compression inlet technology paves the way for an integrated and validated tip-to-tail design of a low-boom supersonic aircraft.

The inlet design and wind tunnel test were planned and conducted by a team of researchers from Glenn, Gulfstream Aerospace, the University of Illinois, and the University of Virginia. The results were presented in June, and the team was honored with the NASA Headquarters 2011 NASA Group Achievement Award.

AeroVironment's high-altitude, long-endurance (HALE) Global Observer made its first flight using hydrogen-fueled propulsion. The 175-ft-wingspan UAV, which can carry payloads of up to 400 lb and fly for up to a week, uses a liquid hydrogen-powered internal combustion powerplant driving four high-efficiency electric motors.

The propulsion system for Boeing's HALE Phantom Eye UAV completed ground tests, ahead of the UAV's flight tests. The start procedures for the hydrogen-powered engine have been established, and the engine speed and four-bladed propeller control were tested in flight conditions as a follow-up to previous tests completed in an altitude chamber. The testing brought together the 16-ft-diam propellers and two Ford 150-hp 2.3-litre, four-cylinder engines. Propulsion for the ground tests was provided by the engine. At high altitudes, a three-stage turbo charger was also used. Moreover, the 150-ft-wingspan demonstrator has completed an integrated fueling, engine run, and defueling test. The flight tests will determine whether it can fly for four days at 65,000 ft.

*NASA engineer Rod Chima works with a low-boom 'relaxed-compression' inlet installed for testing in the NASA Glenn 8x6-ft Supersonic Wind Tunnel.*

Research activity for the AFRL's adaptive versatile engine technology (ADVENT) program continues, now including the design, build, and test of a full turbofan demonstrator engine. GE Aviation will be integrating an innovative portfolio of technologies in the demonstrator engine: a hot section using some advanced ceramic matrix composite materials, a next-generation cooled turbine, an ultrahigh overall pressure ratio, a variable fan design (that adjusts flow and pressure ratio for optimized performance and fuel efficiency at all fight conditions), and a cool third bypass stream flow for high power extraction and thermal management.

by **Dyna Benchergui**

# Electric propulsion

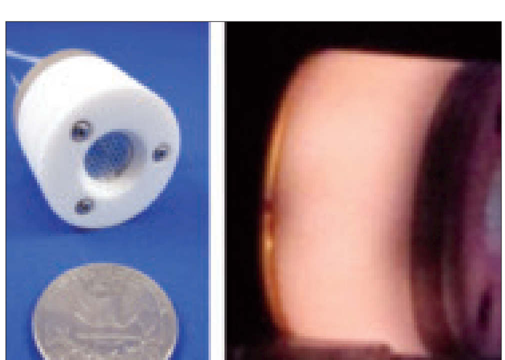
Hall effect thrusters (HET) have been steadily gaining acceptance on Western spacecraft. Space Systems/Loral has now launched seven spacecraft with Fakel stationary plasma thrusters; two more are scheduled for this year, five for 2012; and an additional five for spacecraft currently in construction. The Aerojet/Lockheed Martin Space Systems BPT-4000 HET system has performed nearly a complete orbit transfer of the first Air Force AEHF (advanced extremely high frequency) satellite, firing two thrusters at 9.5 kW as a work-around following an anomaly in the bipropellant propulsion system at the beginning of the mission. Snecma (Safran Group) provided HET thruster module assemblies for five spacecraft, with a sixth planned for the end of this year. Production of TMA units for small GEO satellites and the development of approximately 300-W and 20-kW HETs are under way. Busek's second 200-W HET system is successfully operating in space on the FalconSat-5. Busek's 20-kW HET and the NASA Glenn 20-kW HET, designated 300M, were tested in the Glenn facility and demonstrated excellent performance. The high-voltage Hall accelerator, a high-specific-impulse engineering model HET built by Glenn and Aerojet, has undergone performance testing. Busek characterized a HET fueled by iodine, which appears to be a promising propellant.

Ion thrusters are breaking endurance records. Jet Propulsion Lab's Dawn spacecraft, powered by its three-engine ion propulsion system, entered Vesta's orbit in September. The propulsion system operated for a total of almost 24,000 hr, delivered 6.8-km/sec delta-V, and used 254 kg of propellant. ESA's GOCE (gravity field and steady-state ocean circulation explorer) satellite is successfully operating at an orbit as low as 240 km with propulsion provided by a QinetiQ T5 gridded ion engine system. NASA's NEXT 7-kW ion thruster achieved a total propellant throughput exceeding 645 kg, 24 MN-sec impulse, and 37,600 hr of operation. On the opposite side of the power spectrum are the 1-cm-class RF ion thrusters that can operate at less than 10 W, in development by the University of Giessen in Germany and by Busek in the U.S.

Novel electric propulsion devices under development include the VASIMR thruster by Ad Astra Rocket and the HEMP thruster by Thales Electron Devices in Germany. The VASIMR VX-200 device operating at 200 kW demonstrated 70% thrust efficiency, thrust of 5.8 N, and 4,900-sec $I_{sp}$. The HEMP thruster is in a qualification program and has completed its critical design review. It is intended for small GEO satellites.

Academic researchers in the U.S. are developing several classes of EP instrumentation, including two projects at MIT aimed at the cusped-field thruster and MEMS electrospray thruster module for Cubesats. Each MEMS module is estimated to produce about 50 μN of thrust at more than 3,000 sec $I_{sp}$. George Washington University is developing a microcathode thruster. Measurements performed there and at the University of Southern California indicate that thrust bit is about 10 μN and specific impulse up to 3,000 sec. University of Michigan continued the development of the X2 nested-channel Hall thruster, completing a series of performance tests at powers up to 11.7 kW. In addition, an advanced high-speed dual Langmuir probe measured Hall thruster plasma properties with a temporal resolution of 1 μsec.

New business and research activities were announced. NASA Glenn selected five companies to develop mission concepts for demonstrating solar electric propulsion. The Air Force Research Laboratory selected Busek and CU Aerospace to develop high-performance propulsion for Cubesats. QinetiQ, Aerojet, and EADS Astrium Crisa agreed to jointly market the Xenith propulsion system, based on QinetiQ's T6 gridded ion engine. Astrium (Germany) and Fakel (Russia) have signed a partnership agreement to develop and market the RIT-22 radio frequency ion thrusters. A new large EP facility opened at DLR-Gottingen. And over 300 papers were presented at the 2011 International Electric Propulsion Conference in Wiesbaden, Germany.



*Busek's RF ion thruster is in the 1-cm class.*

by **Vlad Hruby**

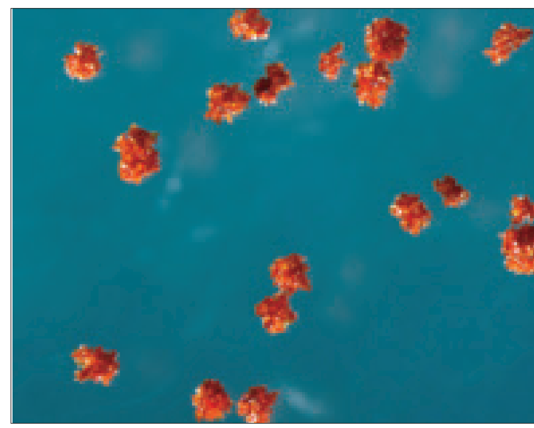
## Energetic components and systems

In spite of the economic downtrend and associated constraints, the energetic components and systems (ECS) industry continued its key role in supporting the successful operations of aerospace safety and launch systems in 2011. The year also marked the passing of an era: The space shuttle Atlantis landed for the last time, ending that program even as unique space exploration projects are still progressing and keeping the ECS community involved.

JPL is finishing final assembly and integration of the Mars Science Laboratory spacecraft, which will deliver an approximately 2,000-lb rover named Curiosity to the surface of Mars. The one-month launch window opened in late November. Entry, descent, and landing (EDL) will employ a SkyCrane landing scheme and is scheduled for August of 2012. The EDL process will involve firing 86 pyrotechnic mechanisms (using 172 NASA standard initiators). The EDL system consists of 39 separation nuts, 22 cable cutters, 20 pyro valves, three pin pullers, one thruster, and one parachute mortar. After landing on the Martian surface, the nuclear-powered rover will use a suite of sophisticated instruments to investigate whether the conditions present on Mars early in its history were favorable for the development of life. The mission is scheduled to last a minimum of 23 months.

Energetic materials provide portable, packaged energy that is essential to the choreographed operations of all ECS items. These chemical systems are constantly being reexamined, updated, or replaced, when practical, as programs and policies evolve. The development and evaluation of 'green' primary energetic materials remains a priority this year. The CAD/PAD (cartridge actuated device/propellant actuated device) R&D and Product Improvement Program Branch at the Indian Head Division, Naval Surface Warfare Center, led the effort and has been working in a joint program with Pacific Scientific, Energetic Materials to identify and test candidate materials. Three promising materials have been identified: the lead azide replacement, DBX-1; the lead styphnate replacement, KDNP; and the tetrazene replacement, MTX-1. DBX-1 has completed compound qualification testing; the evaluation of its performance in components is proceeding. KDNP, which was qualified for military use in 2009, has demonstrated equivalent safety, sensitivity, and output compared to lead styphnate and has been evaluated in a variety of applications with positive results. The proposed tetrazene replacement, MTX-1, offers nearly equivalent sensitization in primer compositions and possesses both higher thermal and hydrolytic stabilities.

Several AIAA and other publications detail the recent accomplishments of this joint effort. Full papers on both DBX-1 and KDNP are forthcoming in the journal *Propellants, Explosives, Pyrotechnics*.



*Optical (77X) micrograph depicts a development lot of DBX-1. Credit: PSEMC.*

Chemring Energetic Devices has developed a primary explosives manufacturing capability that can provide full-scale production rates for materials such as lead azide. This capability is crucial in meeting the current need for heritage energetic materials while 'green' energetics development efforts continue.

The energetic material specification for HNS (hexanitrostilbene) is being reevaluated. The CAD/PAD Engineering Division at the Indian Head Division, Naval Surface Warfare Center, is leading a joint effort by government and industry partners that will modernize the outdated material specification to include recent improvements in manufacturing and instrumental testing techniques. The new processes will prove material equivalence through a series of validation activities. This project will ensure the continued availability and supply chain stability for this critical energetic material.

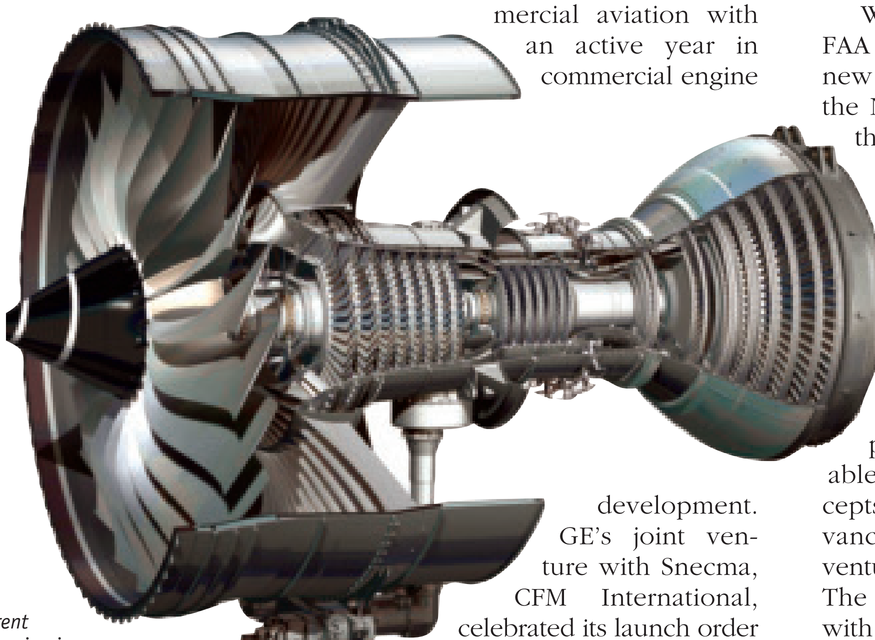
The ECS community continued to provide a strong government, academic, and industrial presence at both the 47th Aerospace Sciences Meeting in Orlando and the 46th Joint Propulsion Conference in San Diego. Many aspects of energetic components, systems, and materials were reported and discussed. Topic areas included new systems development; applications of components; theory and modeling of materials and devices; failure analysis and lessons learned; energetic material concepts, development, and applications; aging/stability; and testing.

by **Bill Sanborn**

# Gas turbine engines

U.S. military turbine engine R&D continued to emphasize energy efficiency this year as a way to improve capability and reduce operating costs. Under the Air Force's adaptive versatile engine technology (ADVENT) program, which is developing variable cycle engine technologies, Rolls-Royce's U.S. military arm Liberty Works and GE Aviation completed fabrication of adaptive fan test rigs, a key technology for ADVENT. Liberty Works successfully completed testing of its fan rig, and GE tests are ongoing. In addition, both companies produced advanced high-pressure compressor test rigs under the Air Force's highly efficient embedded turbine engine, or HEETE, program, which seeks significant improvements in engine thermal efficiency. The Air Force plans to test both compressor rigs next year.

GE Aviation marked 40 years in commercial aviation with an active year in commercial engine development. GE's joint venture with Snecma, CFM International, celebrated its launch order from Virgin America for the LEAP (leading edge aviation propulsion) engine, which will power the Airbus A320neo. The LEAP engine was also selected to power the reengined Boeing 737 as part of the largest aircraft order in history, made by American Airlines. LEAP engines incorporate advanced aerodynamic design techniques, lighter, more durable materials, and leading-edge environmental technologies, making it a major breakthrough in engine technology.



*The Trent XWB engine is currently undergoing testing.*

In addition to the LEAP, GE continued flight testing on the GEnx engine for the Boeing 787 Dreamliner and 747-8 aircraft. The GEnx, which is expected to enter service later this year, will offer 15% better fuel efficiency than current engines in its class.

The Trent 1000, developed for the Boeing 787 Dreamliner by global power systems company Rolls-Royce, has been granted ETOPS (extended twin engine operations) approval by the FAA. This important milestone means that the Trent 1000 is the first engine for the 787 to have ETOPS certification, a critical step toward entry into service. Rolls-Royce also signed an agreement to be the exclusive engine provider for an enhanced version of the Airbus A350-1000 aircraft. The new higher thrust version of the Trent XWB will deliver 97,000 lb maximum thrust, achieved by the inclusion of new high-temperature turbine technology, increasing the size of the engine core, and advanced fan aerodynamics. Currently six Trent XWB engines are being tested, with flight testing scheduled to begin later this year.

Williams International was awarded FAA Part 33 type certification in May for its new FJ44-3AP engine, selected to power the Nextant 400XT, the Hawker 200, and the PiperJet Altaire. State-of-the-art aerodynamics and structural enhancements led to this new benchmark in thrust-to-weight ratio and fuel economy; thrust was increased 8% to more than 3,000 lb, while weight was reduced 3%.

Turboshaft and turboprop engine development also made strides this year. The Army continued its progress on its AATE (advanced affordable turbine engine) program, with concepts under development by GE and Advanced Turbine Engine, or ATEC, a joint venture of Honeywell and Pratt & Whitney. The Army plans to go to engine testing with both concepts next year for a potential transition to upgrade the Army's UH-60 Blackhawk engines. In addition to the Army's program, Rolls-Royce completed the first development test runs of the new RR500 engine, including engine start and accelerations to part power. The RR500 engine is being designed and developed in both turboprop and turboshaft configurations with a takeoff power rating of 450-475 shp. The engine will provide a significant increase in hot and high power over existing products in this power class, while also providing lower acquisition and direct operating costs.

by the
**AIAA Gas Turbine Engines Technical Committee**

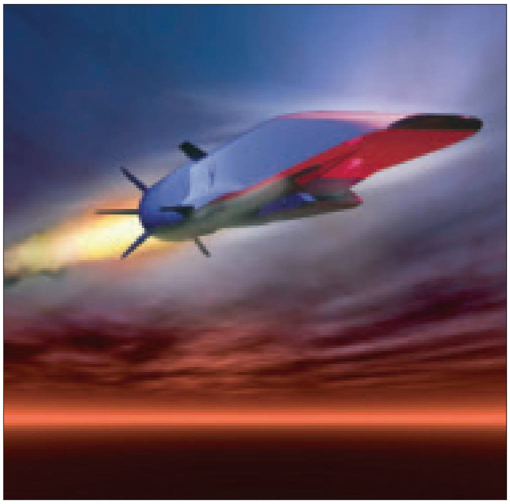
# High-speed air-breathing propulsion

Despite unforeseen challenges, this was a pivotal year for high-speed air-breathing propulsion, with several important events shaping the technology.

The X-51A Waverider attempted its second powered flight on June 13. At 40.3 sec after launch, the vehicle experienced a combustor/inlet unstart and continued to fly controlled, but unpowered, for an additional 97 sec before impacting the Pacific Ocean. Exceptional telemetry data were acquired all the way to splashdown. Many of the subsystems worked as expected, including B-52 safe separation, boost, booster separation, guidance and control, flight actuators, battery power, fuel system pressurization, and flight test instrumentation.

The X-51 investigation centered on both inlet (forebody/inlet isolator) and engine characteristics that were not as expected from data gathered on the ground and on first flight. During boost, the flow through the inlet started at a later than expected Mach number, and higher than anticipated combustion-driven pressures were experienced during the engine start sequence. Inlet/forebody geometry, fuel system delivery to combustor, and clean air combustion characteristics (vs. ground combustion vitiation effects) were all examined as possible causes for the unstart. It is likely that several separate causal factors combined to trigger the unstart. A fault tree was developed with appropriate tests/analyses identified to aid in fault tree node closure.

Aerojet unveiled a novel combined-cycle propulsion concept to achieve seamless operation from Mach 0 to Mach 6+. Known as TriJet engine, the turbine-based combined-cycle concept is attractive for high-speed ISR (intelligence, surveillance, and reconnaissance)/strike platform applications, bridging the existing thrust gap between available turbojets and dual-mode ramjet/scramjets with an ejector ramjet. Aerojet proposed to first configure TriJet for a single-engine demonstrator vehicle, adding that "after extensive flight operation in the Mach 0-4 range, employing existing turbine engine and ejector ramjet propulsion elements, the more robust vehicle could be equipped with a large-scale matching scramjet and used for envelope expansion into the higher Mach flight regime." This approach may overcome the ground test facility limitations as they exist now.



*An artist's rendition depicts the X-51A Waverider in hypersonic flight. Powered by a Pratt & Whitney Rocketdyne SJY61 scramjet engine, the X-51A is designed to ride on its own shock wave and accelerate to Mach 6 (USAF graphic).*

The National Center for Hypersonic Combined Cycle Propulsion, funded by the Air Force Office of Scientific Research and NASA, completed its second year of research. Consisting of teams from industry, government, and academia, CHCCP is seeking an improved understanding of the physics and to model three combined-cycle flow regimes: turbine-to-ramjet mode transition, ramjet-to-scramjet mode transition, and hypervelocity operation. Researchers developed a dual-mode combustion wind tunnel to simulate Mach-5 flight conditions, incorporating new laser diagnostic tools such as tunable diode laser absorption spectroscopy and particle image velocimetry. Modeling of experimental data continues using both RANS (Reynolds-averaged Navier-Stokes) and large-eddy simulation/RANS methods. Advanced filter density function and chemical kinetic models are developed to compute hypersonic turbulent reacting flows.

At CUBRC's LENS II long-duration shock tunnel, a full-scale X-51 vehicle equipped with a generic scramjet flowpath was tested at duplicated Mach-6 flight conditions. Experiments were also conducted in a large-scale combustion duct with a HIFiRE-like flowpath to study mixing and combustion at Mach 5-7 conditions.

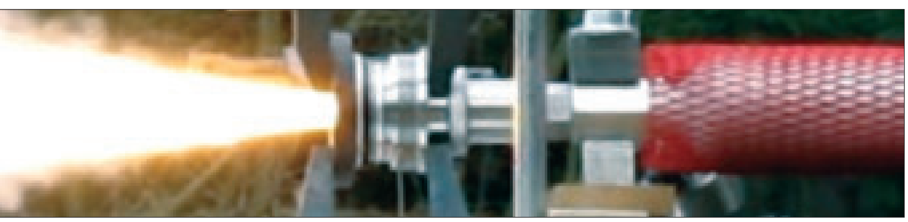
In March, a massive earthquake shook Japan, taking more than 15,000 lives and destroying cities. R&D work at Tohoku University and JAXA's Kakuda Space Center was affected by the devastating event. Fortunately, no casualties were reported in either site, and with minimal damages, activities resumed. Researchers succeeded in measuring second mode pressure fluctuations of the boundary layer transition using a 7-deg half-angle cone at high enthalpy flow conditions in JAXA's High Enthalpy Shock Tunnel. They also proposed a prediction method for boundary layer transition, a needed tool to help optimize hypersonic propulsion technology.

Read more at https://info.aiaa.org/tac/PEG/HSABPTC/default.aspx.

by **Dora Musielak**

# Hybrid rockets

Studies at Stanford University have identified the paraffin-based hybrid as a strong candidate for several in-space missions, such as a Mars ascent vehicle and orbit insertion motor. An apparatus to visualize the liquid layer combustion for paraffin fuels is under development. The combustion chamber allows for multiple vantage points and lighting options for optical measurements. The apparatus is designed for pressures up to 20 atm to enable studies of combustion at supercritical pressures.



*A scaled test motor developed by Aerospace Innovation underwent a successful ignition test.*

Penn State High Pressure Combustion Lab, collaborating with Aerospace Corporation and NASA, presented preliminary work summarizing fuel formulation and characterization for paraffin-based solid fuels containing lithium aluminum hydride ($LiAlH_4$). Solid-fuel grain casting and testing continue. Under a NASA Space Technology Research Fellowship, Penn State graduate student Daniel Larson is developing a high regression rate fuel with high volumetric efficiency for hybrid rocket motors.

Utah State University and Aviradyne Technologies are investigating use of direct digital manufacturing (DDM), or rapid prototyping as a manufacturing process for hybrid fuel grains. Multiple DDM fuel grains made of structural ABS plastic were tested and compared against identically cast HTPB fuel grains with $N_2O$ as the oxidizer. The mean motor thrust was approximately 200 Nt. The DDM-fabricated ABS grains exhibited slightly lower (1.7%) specific impulse but demonstrated significantly greater run-to-run consistency in total impulse and thrust profile.

Aerospace Corporation examined the addition of fuel additives to create several novel paraffin wax-based fuel grains for hybrid rocket motors. Creating a restartable propulsion motor requires a proper ignition system. Currently, hybrid rocket motors are ignited by using explosive squibs and/or gaseous hydrocarbon flames. The squib systems are restartable only with replacement of the squib, which is not possible for motors in upper stages already in flight. Fuel grains that ignite spontaneously upon contact with the oxidizer provide the simplest and most reliable form of start and restart capability. Adding $LiAlH_4$ to paraffin wax produces a wax fuel grain that is hypergolic with several different chemicals. A 50-lb-thrust test paraffin wax/gaseous oxygen test motor has been built and tested. Regression rate measurements have been conducted on several novel fuel grains.

Aerospace Corporation has been researching a novel approach to fabricating hybrid motor fuel grains. A fuel grain is 'grown' or 'printed' using stereolithography, a form of rapid prototyping. Patterns in successive layers of a liquid photopolymer are cured to produce a 3D structure. The structure can be of virtually any shape, so a fuel grain may be produced that has a complex port shape and a large surface area, while also having a large fill-factor. This allows the design of a motor that is highly filled and whose ports are not limited to straight, axially constant shapes.

In an EC cofunded project, FAST20XX, work with scaled hybrid test motors based on $N_2O$ in combination with solid polymers is under way at Aerospace Innovation GmbH, Université Libre de Bruxelles, and the FOI Swedish Defence Research Agency. Different fuel candidates are being considered and tested for application in future launch vehicles.

Extensive research on combustion of liquefying and nonliquefying fuels in hybrid propulsion has taken place at the Faculty of Aerospace Engineering of Technion-Israel Institute of Technology. Polymeric fuels (PMME, HTPB), paraffin-based fuels, and mixed polymer-paraffin fuels have been static-firing tested in a laboratory motor, using gaseous oxygen or nitrous oxide as the oxidizer. A mixed fuel composed of an HTPB matrix filled with synthetic wax particles has proven to have good mechanical properties and a relatively high regression rate (some three times higher than for plain polymer). A theoretical combustion model for a liquefying fuel revealed that the flow of the thin molten fuel layer along the surface may play a significant role in the mass loss mechanism of the fuel and in overall combustion efficiency.

Scaled Composites also conducted the first full-duration hybrid motor firing for SpaceShipTwo.

by **Martin Chiaverini**

# Liquid propulsion

Pratt & Whitney Rocketdyne demonstrated full power operation of the J-2X upper stage rocket engine under development for NASA's manned exploration programs. The J-2X is an upgrade of the J-2, designed to meet future heavy-lift performance and human safety needs. The heritage J-2 proved itself powering the second and third stages of the Saturn V (Apollo) launch vehicle. Fueled by the same propellants (LH2/LO2), the new J-2X will generate 1,310 kN of thrust and can be restarted to send spacecraft on Earth-escape trajectories for a variety of exploration missions.

Aerojet's AJ26 engines, which will provide propulsion for Orbital's Taurus II launch vehicle, were acceptance tested in February. The upper stage engine technology hydrogen turbopump assembly, designed for the next-generation engine program, was tested at the Air Force Research Laboratory in August.

SpaceX (Space Exploration Technologies) develops and produces the Merlin rocket engine to power the Falcon 9 launch vehicle, using liquid oxygen and rocket-grade kerosene propellants. Merlin has the highest thrust/weight ratio of any booster engine ever built, producing 716 kN of thrust in vacuum and having an engine mass of less than 454 kg.

AMPAC In-Space Propulsion extended the qualification of its high-performance 5-lbf MMH/MON engine, demonstrating more than 680 deep thermal cycles and 727 kg throughput at combustion chamber temperatures from 1,425 to 1,650 C. Advanced chamber material development will lead to life extension demonstration testing in 2012. AMPAC-ISP has completed component qualification for a low-cost liquid divert and attitude control system for the Missile Defense Agency, and has assembled a flight-type system for altitude testing late this year.

California State University, Long Beach, with HyperTherm High Temperature Composites and Garvey Spacecraft, expanded to research the use of ceramic matrix composites for improved ablative thrust chambers. Funded by NASA Marshall, they conducted 450-lbf thrust class LOX/methane rocket engine static fire tests.

ESA continued to develop the 180-kN Vinci expander cycle engine designated for the upper stage of the midlife evolution Ariane 5 launcher (A5ME). Testing by Snecma on the P4.1 high-altitude bench at DLR Lampoldshausen explored design improvements implemented for A5ME; testing on the P3.2 bench provided details on regenerative circuit temperature, heat flux, and flow conditions.

ESA's future launcher preparatory program performed refined studies on booster, main, and upper stage propulsion systems for Europe's next-generation launch vehicle. An important milestone achieved in March was the successful completion of the systems requirements review for the main stage, 1,400-kN high-thrust LOX/LH2 staged combustion rocket engine demonstrator (SCORE-D). At midyear, the joint team of Avio, Astrium, and Snecma was awarded a follow-on contract for work leading to SCORE-D subsystems' preliminary design review in 2013. A contract with EADS Astrium was also initiated to develop key technologies for storable propellant engines in the 5-8-kN thrust range. The focus is on combustion chamber cooling with MMH as film and NTO as regenerative coolants. Topics for investigation include heat management, injector performance, and stability.

*The AJ26 is on the test stand at NASA Stennis in Mississippi.*

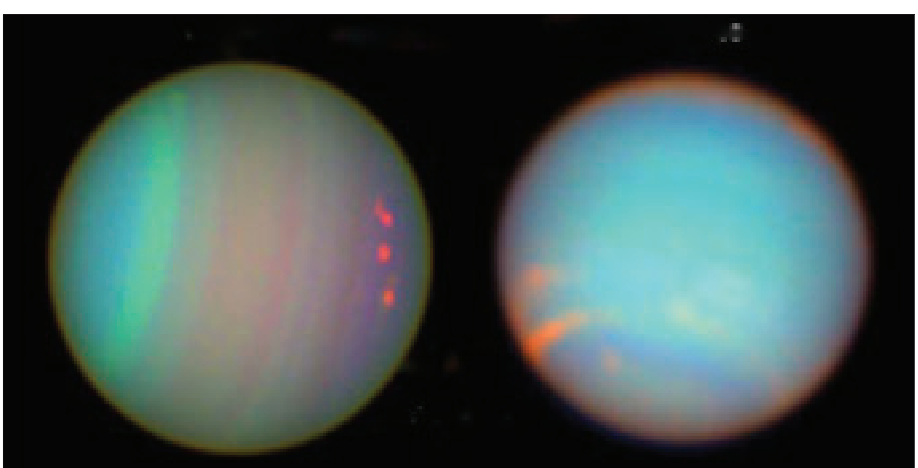
The development of a new LOX/LH2 booster engine, the LE-X, is under way for Japan's next flagship launch system. Scheduled to be complete in 2013, LE-X is an expander-bleed cycle engine. Key to its success will be its high-efficiency turbine, and tests conducted on the fuel turbine showed good agreement with predictions. JAXA also executed an end-to-end high-fidelity simulation of the LE-X to evaluate engine performance and mitigate potential operational hazards. Unfortunately, the space agency had less success with its Venus orbiter Akatsuki (Dawn). The craft's main engine failed to complete the first Venus orbit insertion burn in December 2010. In-flight tests conducted in September of this year showed thrust at one-third to one-fourth of the expected level. Contamination of a check valve by oxidizer and fuel residual products is the suspected culprit.

by the **AIAA Liquid Propulsion Technical Committee**

# Nuclear and future flight propulsion

Atmospheric mining of the outer planets can be a powerful tool in extracting fuels to allow fast human and robotic exploration of the solar system. Preliminary designs of aerospacecraft with gas core engines for mining the outer planets were developed at NASA Glenn. The analyses showed that such engines can reduce the mass of atmospheric mining vehicles very significantly, enabling a reduction of 72-80% over NTP (nuclear thermal propulsion) solid core powered mining vehicles.

Although this reduction in the mass of the overall mining system is important, a fissioning plasma gas core rocket is much more complex than the more traditional solid core NTP engines. Flight rates necessary for fueling an interstellar-class vehicle with a 50,000-metric-ton propellant load have been estimated. While up to 20 mining flights a day would be needed to meet a 20-year assembly time, a more moderate number of daily flights would be required if the assembly time were relaxed to 50 years.



*Uranus and Neptune may provide vast quantities of accessible fuels.*

If the assembly time is extended to 100 years, the number of flights is reduced to three per day for the 0.5-metric-ton payload (per mining flight) case, and less than one per day with the 2-metric-ton payload case. The assembly time of 100 years may be impractical, but it does reduce the flight times to only one to three per day.

Based on these analyses, there are likely several possible future avenues for effectively using the gases of the outer planets to fuel exciting exploration missions. Uranus and Neptune offer vast reservoirs of fuels that are more readily accessible than those of Jupiter and Saturn and, with the advent of nuclear fusion propulsion, may offer us the best option for the first practical interstellar flight.

A novel model for air transport has been proposed in a study at Cranfield University and analyzed for feasibility. Out of many future alternative sources of power and propulsion, nuclear propulsion seems to be one of the practical future methods for travel. According to the proposed concept, all the chemically propelled aircraft traveling on a particular sector could be optimized only for takeoff and climb, which would result in increased efficiency.

After reaching a designated height, these optimized aircraft would be carried from one location to another by a nuclear-powered aircraft. At the destination, chemically propelled aircraft could land using their own onboard engines. Optimizing a chemical aircraft for takeoff and climb and then shutting off the engine for cruise results in less fuel consumption, lower takeoff weight, and reduced emissions.

Historically, researchers concluded that the operating cost of nuclear-powered aircraft could be substantially reduced by increasing the gross weight—increased aircraft size will make it more feasible to convert the present fleet of aircraft to the proposed nuclear-powered air transport cycle.

A large number of aircraft accidents happen during either landing or takeoff, or because of human error. Nuclear-powered flight, which will have no takeoff or landing and no human pilots, will substantially lower the possibility of an accident. The decreasing availability of fossil fuels for air transportation also would be less of a problem with the proposed nuclear-powered air transport model, which would save substantial amounts of fuel: Reduction in the $NO_x$ (oxides of nitrogen) emissions is 33% for short-range aircraft of 1,000-km range; for the 10,000-km range case, this reduction is up to 80%.

More information is available at the SBIR (Small Business Innovation Research) fuels and space propellants Web site, www.grc.nasa.gov/WWW/Fuels-And-Space-Propellants/foctopsb.htm.

by **Bryan Palaszewski**

# Propellants and combustion

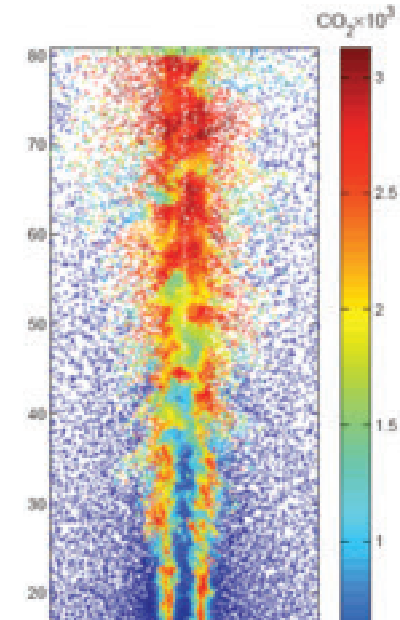
The National Center for Hypersonic Combined Cycle Combustion, funded by AFOSR and NASA, completed its second year of research. The center seeks improvements in the ability to understand physically and model three combined-cycle flow regimes: turbine-to-ramjet mode transition, ramjet-to-scramjet mode transition, and hypervelocity operation.

Fundamental computational modeling techniques used by the center include production-level Reynolds-averaged Navier-Stokes (RANS), large-eddy simulation (LES)/RANS, and development of advanced filtered density function (FDF). LES/RANS, developed by North Carolina State University, used a blending function to transition from the LES of the flow field to the RANS near walls. The University of Pittsburgh and Michigan State developed an advanced FDF technique, termed energy-pressure-velocity-scalar or EPVS, for turbulent combusting flows. The University of Buffalo uses direct numerical simulation to provide data used by both the LES/RANS and FDF solution methodologies.

CFD methodologies require computationally efficient implementation of accurate combustion chemistry. Ethylene, a major pyrolysis product of real fuels, is used in the research program as a representative hydrocarbon fuel. A University of Virginia team, starting from a 111-species detailed mechanism for ethylene (USC Mech II), has developed and validated an accurate 38-species skeletal mechanism and a 24-species reduced mechanism. Uncertainty analysis has been used to identify the critical rates for which more accurate experimental data would be valuable. At Cornell researchers pursued another dimension-reduction approach, namely rate-controlled constrained equilibrium, or RCCE. Certain species are selected as 'constraints'; the remaining species are assumed to be in constrained chemical equilibrium. A 'greedy algorithm with local improvement,' or GALI, has been developed to select near-optimal constrained species. All the approaches have been implemented and tested for the test case of an LES/FDF simulation of a nonpremixed piloted jet flame. The different descriptions of the chemistry are implemented using in situ adaptive tabulation. The combination of the tabulation and reduction schemes reduces the computer time required by a factor of 10,000, making LES/FDF computations feasible. The combined approaches have been implemented in parallel, and good scaling is observed in all tests (up to 9,000 processors). These advances will facilitate future LES/FDF calculations of combustion in combined-cycle flow regimes.

At the Laboratory for Computational Physics and Fluid Dynamics, Naval Research Lab (NRL), simulations are used to study detonation for both propulsion and hazard applications. Detonation wave engine concepts are promising, as they could provide up to 25% improvement in fuel efficiency. In a rotating-detonation engine studied at NRL, a detonation wave propagates around an annular ring combustion chamber consuming air/fuel that is injected axially. Simulations are used to examine the flow field and understand the relationship between input and output pressure and the effects of engine sizing parameters on performance. Recent studies investigated the effect of injection patterns on the detonation structure and resulting performance.

*A scatter plot of $CO_2$ was produced from an LES/FDF simulation of a non-premixed piloted jet flame.*

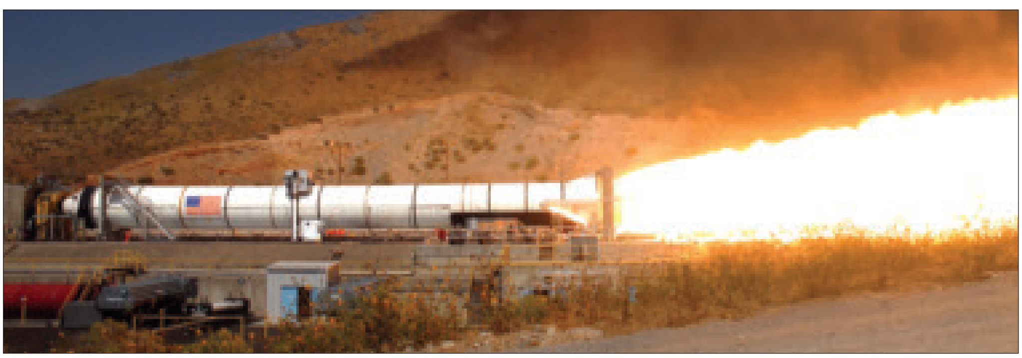



Formation of a supersonic detonation from a subsonic flame (deflagration-to-detonation transition, or DDT) can occur in a wide variety of environments ranging from experimental systems on Earth to astrophysical thermonuclear supernovae explosions. Studies show that in confined systems, walls and obstacles play a key role in causing the pressure increase and acceleration of the flame, thus creating conditions necessary for the detonation ignition. Detailed numerical simulations from NRL (in collaboration with Sandia) of high-speed turbulence interaction with unconfined, subsonic, premixed, turbulent flames in stoichiometric $H_2$-air and $CH_4$-air mixtures showed, however, that such flames are inherently unstable to DDT even without assistance from preexisting shocks or obstacles. Understanding this new mechanism of detonation formation will help to mitigate the threat posed by uncontrolled DDT to chemical storage and processing facilities and to mining operations.

by **Steven Pope, Alexei Poludnenko, Douglas Schwer, Joanna Austin,** and **Yiguang Ju**

# Solid rockets

Tactical, strategic, and launch system arenas saw progress in solid rocket motor technology, through successful tests of in-service, next-generation subsystems and significant production milestones. In April, Raytheon completed the first flight test of a Standard Missile-3 (SM-3) Block IA against an intermediate range ballistic missile, marking the 19th successful SM-3 intercept. In August, Aerojet accomplished key developmental milestones on its SM-3 Block IB throttleable divert and attitude control system by completing a series of full-up system tests.



DM-3 is NASA's largest and most powerful solid rocket motor ever designed for flight.

Production milestones and sustained flight test achievements were reached for several in-service systems. Lockheed Martin delivered the 1,000th Patriot Advanced Capability-3 (PAC-3) missile to the Army in September 2010, and this March the enhanced version, the PAC-3 Missile Segment Enhancement, successfully intercepted a tactical missile target at White Sands. Also in March, the Navy and Lockheed Martin conducted a successful test flight of a Trident II D5 fleet ballistic missile. The three-stage, solid-propellant D5 was launched from the submerged submarine USS Nevada in the Pacific Ocean, marking the 135th consecutive successful test flight of the D5 missile since 1989—a 22-year record of reliability unmatched by any other large ballistic missile or space launch vehicle. Orbital Sciences carried out the 25th launch of its Coyote supersonic sea-skimming target vehicle in July 2011 supporting the Navy's ongoing ship self-defense exercises.

Progress was made for the next-generation joint air-to-ground missile (JAGM), a single-motor solution for fixed- and rotary-wing platforms. In May, Raytheon and Boeing completed a series of tests of JAGM. The rocket motors designed by Boeing and subcontractor ATK were subjected to 5-20 thermal cycles of -45 to 160 F and successfully fired, meeting all test objectives. In August, Lockheed Martin successfully demonstrated its Aerojet-supplied JAGM minimum-smoke rocket motor in fixed-wing aircraft operating in severe weather environments. Lockheed Martin's JAGM motor had been demonstrated to meet or exceed rotary-wing requirements in prior environmental testing.

In June, Orbital Sciences successfully launched the Dept. of Defense ORS-1 satellite on a Minotaur I rocket. The launch was the 21st for the Minotaur family since 2000. The final flight of space shuttle Endeavour occurred in May, using ATK's reusable solid rocket motors. The last three launches of the shuttle took place this year: Discovery, Endeavour, and Atlantis. As a tribute, Endeavour had a fired case from its first flight (STS-49) and Atlantis had an STS-1 fired case in their left boosters. The shuttle program's final liftoff occurred in July with the picture-perfect launch of Atlantis, culminating a remarkable three-decade-long program in space exploration.

Test successes in 2011 offer encouragement as the industry looks forward to the next-generation solid rocket motors for commercial launch and heavy-lift vehicles. In September, ATK conducted a third successful ground test of the five-segment solid rocket motor, Development Motor 3, based on the four-segment RSRMs. This is NASA's largest and most powerful solid rocket motor ever designed for flight. Aerojet played a key role, supplying five solid rocket boosters (SRBs), in the successful launch of United Launch Alliance's Atlas V from Cape Canaveral carrying NASA's Juno spacecraft toward Jupiter, the 13th successful Atlas V launch with Aerojet SRBs.

Early this year, ATK and Astrium (an EADS company) announced the Liberty rocket joint venture. ATK would supply the human-rated first stage, developed under NASA's Space Exploration Program, which is derived from the space shuttle's SRBs. Astrium, developer and manufacturer of the Ariane 5 launcher, working with Snecma, would provide Liberty's liquid fueled second stage.

by **Barbara A. Leary, Robert E. Black III,** and **Clyde E. Carr Jr.**

# Terrestrial energy systems

This year again saw considerable activity in the development of green energy concepts, more efficient utilization of fuels, and efforts to find alternative fuels to meet increasing demand.

Solar energy is breaking through the clouds. Although their contribution to the world's energy consumption is still very small, solar technologies have great potential to strengthen national security, mitigate global climate change, and reduce air pollution. They can also improve third world conditions by providing access to electricity and helping to reduce deforestation. These factors, along with the increasing maturity of solar technologies and research, have set the stage for a significant shift toward solar energy, and for an accompanying thrust in the R&D of related energy conversion technologies.

Driven by dramatic cost reductions in photovoltaic (PV) panels, lenses, and inverters, and by government incentives and legislation, PV system sizes and the number of PV installations in the U.S. are increasing significantly. Just a few years ago a solar PV installation of 500 kW was considered very large; today many industrial rooftops sport systems of several megawatts, and desert installations in the range of hundreds of megawatts are being planned.

PV plants are not only changing the pattern of world energy use and reducing carbon dioxide emissions but are also having a dramatic personal effect on people in third world countries. Today, about 1.5 billion people in developing nations lack access to electricity. Energy from traditional sources must often be imported from richer countries and paid for in hard currency. By moving the production of energy closer to the consumer or, even more radically, by turning potential consumers into producers as well, renewable energy has begun to make inroads in creating a more energy-inclusive third world.

Of those renewable energies, solar is the most functional, immediate, and easiest to obtain. Installations of PV systems, along with their inexpensive maintenance, have stimulated the development of energy entrepreneurship, which generates economic opportunity and jobs. Worldwide, institutions such as the Catholic University of Milan, in collaboration with EFrem (Energy Freedom), are facilitating this development by aiding in the design and installation of solar power plants, preparing market studies, and training managers and technicians.

*A photovoltaic panel is installed in Nairobi, Kenya.*

An emerging solar energy conversion technology is the concentrating solar power (CSP) plant. In CSP plants, electricity is generated by traditional power-generating (typically steam) turbines where working fluid is heated by concentrated radiation from the Sun. So far, they have proven slightly more cost effective than PV on a large scale, but, more important, they can be cofired with natural gas for periods of low solar isolation. For example, a new receiver design being explored at San Diego State University will enable a CSP plant to operate with gas turbines instead of steam turbines. This eliminates the requirement for cooling water while increasing efficiency.

Storage is a big challenge for solar electric technologies. Wind energy is facing the same issue in certain regions, where within a half-hour or so, a gigawatt can come online (or go offline). As the Sun moves throughout the day, or clouds come and go, PV and CSP plants can suffer huge swings in output. Currently, CSP plants have the advantage over PV in that heat can be stored in molten salt or other media, since battery technology is not adequate to store that much electricity directly. One promising technology at San Diego State is high-temperature phase change storage using binary alloys that can work in conjunction with the gas turbine mentioned above.

Long constrained by high costs and inadequate technology, solar energy may finally break through to the mainstream in the next few decades. Cooperation with government and dedication among scientists and engineers researching new materials and technologies will be needed for it to reach its full potential.

by **Gustaaf B. Jacobs** and **Fletcher J. Miller**

# Life sciences and systems

The life sciences and systems (LSS) community's aerospace-related activities are focused on enabling human exploration of space. Science and technology efforts at space organizations around the world are addressing life support needs for future space endeavors.

Anticipation of future visits to a near-Earth asteroid and/or Mars are driving some current life support efforts to address requirements for such missions. Without clearly stated goals, however, integrated systems cannot be defined. Life sciences (LS) efforts are addressing problems associated with long-duration space stays, including physiological deconditioning, and the effects of radiation on crews.

Advanced exploration system projects have been proposed and accepted, with project management named, and are nearly ready for implementation for LSS related areas—the multimission space exploration vehicle (MMSEV), EVA suit and life support; suitport; deep space habitat definition; analog missions; logistics reduction and repurposing; water recovery; spacecraft fire safety demonstrations; radiation protection; atmosphere resource recovery; and environmental monitoring. The $CO_2$ and moisture removal amine sorbent technology has been flown to the ISS and implemented as a development test objective.

NASA centers are working to develop the systems needed to maintain breathable air in spacecraft: Johnson tested a pressure swing amine bed technology for potential use on Orion and EVA systems; Ames continued development of a closed-loop $CO_2$ removal system to reduce power associated with water recovery and integrate $CO_2$ compression; and Marshall has made progress on technologies for recovery of $O_2$ from $CO_2$ and $H_2$ derived from methane.

*The deep space habitat simulation in Arizona featured a testing lab, experimental habitation module, and hygiene and airlock modules, with multimission space exploration vehicles in the vicinity.*

An Office of the Chief Technologist project, next-generation life support systems, will sponsor follow-on work on Bosch-related $CO_2$ reduction beginning in FY12.

Desert RATS (research and technology simulation) testing in the Arizona desert simulated operations for exploration of a near-Earth asteroid. Desert RATS featured two MMSEVs and a deep space habitat that included a laboratory module, a University of Wisconsin-provided inflatable habitat, an airlock/dust mitigation module, and a hygiene module. Simulations involved asteroid MMSEV activities, EVAs, and support activities based in the habitat for multiday missions. Crews occupied the habitat for most of the two-week testing period.

The plant signaling experiment, conducted on board the ISS in July, was a collaboration by NASA Ames and North Carolina State University to understand the molecular mechanisms plants use to sense and respond to changes in their environment. *Arabidopsis* plants were grown in the European modular cultivation system to allow comparison of global transcript and protein profiles of the wild type and transgenic plants under microgravity and 1-*g* conditions. The goal is to use this knowledge to improve crops on Earth and design plants to tolerate extreme and extraterrestrial environments.

Two Italian astronauts, Paolo Nespoli and Roberto Vittori, executed eight LS experiments sponsored by the Italian space agency, which has begun work on an external platform devoted to exobiology.

The Mars500 project continued simulating the operations and confinement of a 500-day mission from Earth to Mars. The 'mission' has generated unique data—nobody has been isolated as long as these six marsonauts. Their stay ended on schedule when the hatch opened on November 4.

The emerging commercial spaceflight industry is adding an exciting new dimension to space activities. In late 2010, the FAA formed a new Center of Excellence for Commercial Space Transportation, charged with conducting research across areas such as space traffic management, launch vehicles and technologies, human spaceflight, and industry viability. Future transport of crew and cargo to and from LEO is now envisioned to be provided by the private sector, which broadens the role of the life sciences and support community and opens the door for NASA to set its sights on deep space exploration.

by **Jeff Johnson**

# Space architecture

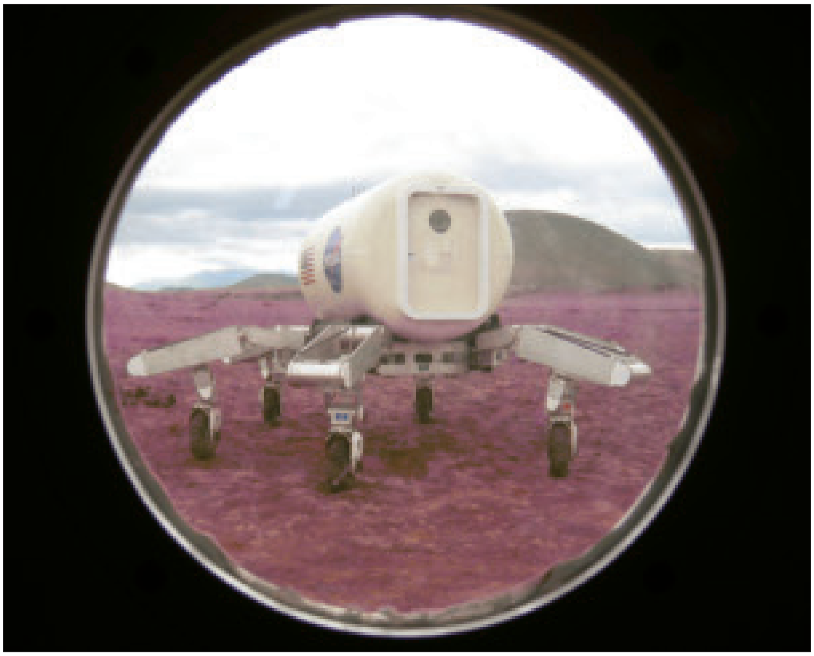
The next big human missions to the Moon, Mars, or elsewhere have not yet arrived on international drawing boards. In the past year, however, the space architecture community has pressed on with habitation designs for these future missions, continuing to envision the engineered cocoons that humans will need to survive on alien and remote surfaces.

In the U.S., NASA has built a prototype called the habitat demonstration unit–deep space habitat (HDU–DSH) and has tested it in the desert north of Flagstaff, Arizona, under the NASA desert research and technology studies (D-RATS) campaign. The habitat is a 5-m-diam. cylindrical shell with the horizontal end caps forming the floor and roof. Inside, it has one level of accommodation to support a three- or four-person crew for 14-30 days. This year NASA held a competition called the X-Hab Academic Challenge to build an inflatable loft for mounting on the habitat's roof to expand the crew accommodation. Three universities competed to build the loft structure. The University of Wisconsin-Madison's Badger X-Loft design was the winner. It will go to Arizona for installation in the next round of NASA field tests.

In parallel, space architects from JPL have developed a small habitat capsule that rides on top of the all-terrain hex-limbed extra-terrestrial explorer, or ATHLETE, that docks with the larger habitat.

In Europe, work continues on long-range studies for fixed and mobile habitats destined for the Moon or Mars. Architect Barbara Imhof and her associates at the Liquifer Systems Group in Vienna, Austria, have been exploring a concept called RAMA (rover for advanced mission applications). Designed with Thales Alenia Space under an ESA study, RAMA incorporates a dual suitport with two surface activity suits sealed directly into the pressurized rover's body. The rear-entry suitport concept was pioneered by architect Marc Cohen and colleagues at NASA Ames. It reduces the problem of dust and other contaminants that are released during the doffing of suits when a conventional airlock is used.

The RAMA concept features innovations in the human factors area, such as a cockpit chair that transforms into a bed and workstation. Rover accommodation is designed to support a two- or three-person crew on a surface sortie of about 40 days.



*Seen from inside the HDU-DSH habitat through a porthole, the ATHLETE vehicle bearing the small capsule approaches the stationary habitat for a docking test. Photo: David A. Nixon.*

Architecture in the hostile space environment is a field closely related to architecture in extreme environments on Earth. Many of the habitability and human factors challenges are similar if not identical. A good illustration of this is the Halley VI Antarctic research station designed by Hugh Broughton Architects of London, supported by AECOM. Created for the British Antarctic Survey, Halley VI was the result of an international architectural competition. It has a modular design and, like the ISS, is assembled from a prefabricated kit-of-parts that arrives at the operations location ready to be berthed together. Its modules can move to a safer location when the station's local portion of the Brunt Ice Shelf threatens to break off as a giant iceberg. This is equivalent to the periodic reboosting of the international space station's orbit to maintain a safe altitude.

Halley VI fuses cutting-edge engineering with innovative accommodation facilities and outfitting to combat the isolation of life in the extreme Antarctic environment. Hydraulic legs allow the modules to climb above rising snow levels when stationary, while ski-based foundations enable their repositioning on the Brunt Ice Shelf. In the Austral summer of this year (January and February), the construction team moved the individual modules 15 km to their first operational site and linked them together for final construction and handover to the British Antarctic Survey in 2012.

by **David A. Nixon**

# Space automation and robotics

On February 24, space shuttle Discovery was launched into orbit for the last time. In addition to the crew of six astronauts, the STS-133 mission included a robotic passenger, NASA's Robonaut 2 (R2). This two-armed humanoid robot is the latest result of a long-term NASA effort to develop robots that have manipulation capabilities similar to those of suited astronauts. In the future, dexterous robots will be able to make use of hand tools without modification and perform extravehicular activity work, enabling a reduction in the amount of consumables used during human missions.

NASA astronaut Cady Coleman poses with Robonaut 2 in the Destiny laboratory of the ISS in March. Courtesy NASA.

NASA began formal testing of R2 on the ISS in late summer as part of the human exploration telerobotics (HET) project. The purpose of HET is to assess how advanced remotely operated robots can improve the productivity of human explorers and increase the scientific return of human missions. To do this, HET is conducting tests with a variety of robot systems remotely operated by ISS astronauts and by ground controllers on Earth. These systems include R2, the MIT SPHERES (synchronized position hold engage and reorient experimental satellites) free-flyers, the NASA Ames K10 planetary rovers, and the JPL ATHLETE (all-terrain hex-limbed extraterrestrial explorer) robot.

With the successful completion of the STS-135 on July 21, the shuttle remote manipulator system (SRMS), or Canadarm, was officially retired after having flown on more than 50 missions. The SRMS arms from Discovery and Atlantis will be displayed along with their respective shuttles. The Endeavour arm is being removed and will be on display in Canada.

At this year's International Conference on Robotics and Automation, held in Beijing, Chinese officials announced several lunar rover missions. The first, to fly in 2013, will be an autonomous 120-kg rover to explore Sinus Iridium. The robot is powered by solar panels during the lunar day and kept alive through the lunar night using a U238 RTG (radioisotope thermoelectric generator). Following the rover mission, China expects to conduct a sample return mission in 2017.

In April, ESA tested its ExoMars drill in Mars analog conditions. The drill can penetrate to a depth of 2 m and return core samples by opening and closing the coring port at the drill head. The drill also has a sapphire window on the side of the drill string for the Mars MISSE (multispectral imager for subsurface studies experiment). This imager can take readings from the inside of the bore hole. ESA plans to deploy the drill on Mars as part of a joint 2018 mission with NASA.

At the end of May, NASA announced that it had formally ended the mission of its Mars exploration rover Spirit. The agency made this decision after being unable to reestablish communications with the rover for more than a year. NASA concluded that the rover had likely not survived the recent Martian winter because of inadequate power for its survival heaters. Spirit landed on Mars on January 3, 2004, for a three-month mission, but surpassed all expectations by operating until March 22, 2010.

Elsewhere on Mars, the Opportunity rover (Spirit's twin) continues to establish new records for Mars exploration. In August, Opportunity arrived at Endeavour Crater after traveling for almost three years across a distance of 13 mi. (21 km). Scientists are planning to use Opportunity to sample new types of rocks in Endeavour, particularly clay minerals that may have formed in early, wet conditions on Mars. JPL operates Opportunity remotely, from Pasadena.

by **Terrence Fong** and **David P. Miller**

# Space colonization

The end of the space shuttle program represents a symbolic interruption on the path toward space settlement. The space settlement designs created in the 1970s presumed use of the shuttle for launching construction elements. Although cost realities led to recognition that the shuttle was not an economically viable tool for the construction of space settlements, the vehicles offered a capability for large on-orbit construction projects. Now on-orbit construction capabilities are gone, and it is uncertain when and how they will be restored.

Tangible evidence of a path toward future space settlement is, however, provided by completion of the international space station. The ISS can now support a long-term crew of six, allowing more time to conduct scientific research and to develop a better understanding of the challenges and concerns associated with living in space habitats.

Work on the deep-space multipurpose crew vehicle (MPCV) continues, four companies are working commercial crew development contracts, and the design of the next-generation Space Launch System was announced in September. Reflecting more ambitious U.S. interest in space habitation was DARPA's announcement of a 100-year starship study. Expanding international interest in future space habitation was confirmed with China's launch of the first module of a future space station.

Widely available in bookstores is Haym Benaroya's *Turning Dust to Gold: Building a Future on the Moon and Mars*; although written as a 'historical record' from the year 2169, it is a serious look at infrastructure and design considerations for future space settlement. Also by Benaroya is *Lunar Settlements*, a compilation of papers from a Symposium on Lunar Settlements at Rutgers University. The AIAA-published book *Out of this World–The New Field of Space Architecture* includes a chapter on 'lunar architecture and urbanism.' And *The Highest Frontier* by Joan Slonczewski, a fictional account of life in an orbital university, weaves challenges of space living into the story.

Numerous papers related to space settlements were offered this year at the AIAA Aerospace Sciences Meeting, the National Space Society (NSS) International Space Development Conference, and AIAA Space 2011. The NSS Web site features an online library with a collection of documents covering space settlements, solar power satellites, planetary defense, and habitations on the Moon and Mars. NSS has also started an Internet-based peer-reviewed *Space Settlement Journal* that began accepting papers this year.

Strong student interest in space settlement was demonstrated by about 1,000 participants in the AIAA-sponsored International Space Settlement Design Competition, which included semifinals in India, the United Kingdom, and Houston, Texas, with the final selection in Houston. Hundreds of students worldwide also submitted entries for the NSS space design contest.

Perhaps a reflection of interest in, and uncertainty about, future large-scale habitation of space is the 2011-2012 high school debate topic for the National Forensic League, "Resolved: The United States federal government should substantially increase its exploration and/or development of space beyond the Earth's mesosphere." For advocates of space settlements, the clear answer is "Of course, development of space is what humans are destined to do." However, the fact that this is a debate topic suggests that there are equally compelling arguments against expansion of human activities in space.

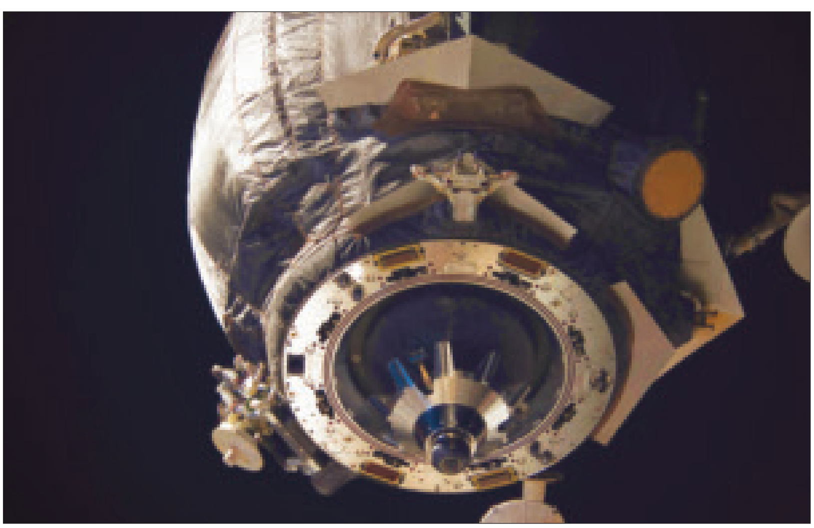

*Astronaut Sandra Magnus exercises on the advanced resistive exercise device in the Unity node of the ISS. Long stays on the ISS will provide a better understanding of some of the challenges facing future space colonists.*

by **Mark G. Benton Sr.** and **Anita Gale**

# Space logistics

Space logistics is the theory and practice of driving space system design for operability, and of managing the flow of materiel, services, and information needed throughout a space system life cycle. This was a big year for ISS sustainment, involving delivery of over 25 tons of storage volume, propellant, oxygen, water, food, medical supplies, and spare parts. Moving this much cargo required a multinational effort by Japan, ESA, the U.S., and Russia and includes plans for the world's first commercial ISS cargo demonstrations via a SpaceX Falcon 9/Dragon flight scheduled for this month and an Orbital Sciences Taurus II/Cygnus flight early next year.

The unmanned Japan Aerospace Exploration Agency (JAXA) Kounotori 2 (HTV2) led with a January 27 ISS rendezvous—marking JAXA's second delivery (4.2 tons of supplies) to the ISS. HTV2 is now the only vehicle able to deliver both internal and external cargo. The external cargo is mounted to an exposed pallet that sits in the HTV's unpressurized section. The HTV2 flight recorded several firsts: It was the first flight of unpressurized spares and hardware on a vehicle other than a shuttle; it was the first robotic transfer of the exposed cargo pallet using both Canadarm2 and the Japanese robotic arm; and it was the first Dextre-based robotic transfer of external stores from the pallet to other locations.



*The Progress 41 supply vehicle departed from the ISS on April 22. Filled with trash and discarded items, it descended to a destructive reentry into Earth's atmosphere over the Pacific Ocean.*

ESA's unmanned ATV2, Johannes Kepler, docked with the ISS on February 24, bringing over 7 tons of fuel, oxygen, and supplies. This follows the 2008 Jules Verne ATV mission, which carried only about one-third as much cargo. It is now the largest and heaviest vehicle that can supply the station and serves in several important roles, including cargo carrier, temporary storage facility, and space tug for adjusting the station's orbit. It can deliver about three times more fuel than the Progress vehicle.

Final shuttle flights STS-133 (Discovery), -134 (Endeavour), and -135 (Atlantis) all performed significant logistics support functions for the ISS. Discovery's delivery of the Leonardo multipurpose module adds critical permanent storage space to the ISS. Discovery also transported the ExPRESS Logistics Carrier (ELC) 4, which in turn holds several orbital replacement units (ORUs). Endeavour's final mission included ELC3 with more ORUs that were too large or too heavy for other transport spacecraft to carry. Endeavour also left behind its orbiter boom sensor system, which can facilitate station repairs, as demonstrated by a torn solar panel fix during STS-120. Significant logistics highlights of the Atlantis flight included delivery of the robotic refueling mission for on-orbit satellite refueling testing, and Earth transport of the 1,400-lb broken ammonia pump module for failure analysis and repair. The shuttle's demise means that the Soyuz is now the only viable path for down-mass transportation, but it cannot accommodate ORUs of the ammonia pump's size or weight.

ISS resupply must rely primarily on Russian Progress flights until other options mature. The five Progress missions planned for this year each carry an average of about 3 tons of supplies. This logistics strategy was challenged on August 24 when Progress 44 failed to reach orbit because of a Soyuz rocket anomaly—marking the first Progress ISS mission failure, and raising questions about the ability to provide short-notice resupply after launch failure. Effective long-term sustainment will require robust, responsive launch options.

While the ISS dominated the space logistics field this year, other exciting developments are under way. NASA is actively exploring in-space fuel depots, as seen in the ISS robotic refueling mission and in the contracts awarded to Analytical Mechanics Associates, Ball Aerospace, Boeing, and Lockheed Martin to explore cryogenic fluid management technology and infrastructure. Space-based fueling is vital for enabling an extended human presence in space.

by **Alan W. Johnson**

# Space operations

This year saw the second flights of both ATV and HTV resupply vessels to the ISS. With the end of shuttle operations, these two vessels mark the next phase of international cooperation for the space station. ATV-3 is already in Kourou ready for launch early next year. The year also brought two landmark events in operations ground systems, with the Air Force's multimission spacecraft operations center going live at the beginning of the year, marking a new milestone for responsive space missions, and the Army's first Wideband Space Operations Center opening in Hawaii in February.

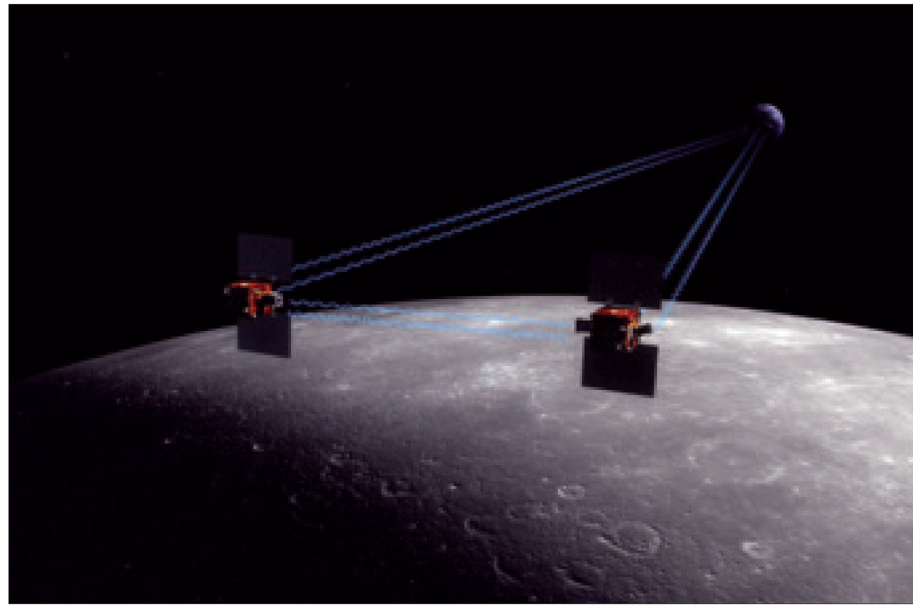
In the field of science operations, NASA's Juno mission launched in August to support experiments investigating Jupiter's origin and evolution: Jupiter is the solar system's oldest planet and may hold secrets for the others. This launch was closely followed by NASA's GRAIL (gravity recovery and interior laboratory) Moon mapper mission, sent aloft in September. GRAIL will map the gravitational field of the Moon to help determine the nature of its interior composition.

Internationally, April's ResourceSat-2 launch marked the continuation of India's advanced remote sensing data provision, adding a hosted Canadian AIS payload. The same flight launched Singapore's first national satellite: X-Sat provides an imaging remote sensing platform. August also saw NigeriaSat-2 and NigeriaSat-X launches, which used Surrey Satellite buses. The Nigerian operations teams were trained by SSTL personnel. ESA's Rosetta comet mission started a 31-month hibernation in June, the satellite already having set records for distance from the Sun for a solar-powered spacecraft.

Atmospheric science suffered a setback in March: NASA's Glory mission (atmospheric composition, carbon cycle, biogeochemistry) was lost after its Taurus XL launch suffered a fairing separation failure.

The 6.5-tonne upper atmosphere research satellite (UARS) reentered on September 24 over a remote part of the Pacific Ocean. The UARS reentry was timely; it was launched by the shuttle 20 years ago.

NASA gave SpaceX the go-ahead to combine commercial-off-the-shelf Demo 2 and Demo 3 flights into a single, first-of-its-kind private mission to the ISS, originally scheduled to launch on November 30 and dock with the station nine days later. That date had to be postponed after the Russian Progress 44 resupply ship bound for the ISS on August 24 crashed after suffering a malfunction in a gas generator of the Soyuz third-stage engine, according to a Roscosmos report. This rocket is similar enough to the variant used to launch astronauts to the station that officials of the Russian space agency temporarily grounded flights of both while investigating the cause of the Progress mishap. Flights resumed on October 30 with the successful launch of Progress 45. SpaceX has said that December 19 is the first "in a range of dates that we would be ready to launch pending NASA safety and ISS partner approval." The company has taken the lead position among several firms, including Orbital Sciences, Sierra Nevada, Boeing, and Blue Origin, working on their own designs to replace the shuttle.



*The twin GRAIL spacecraft fly in tandem orbits around the Moon for several months to measure its gravity field in unprecedented detail. Credit: NASA JPL.*

Some commercial entities have demonstrated rapid progress in spacecraft systems capable of ending U.S. reliance on Russia for space access. They see NASA's latest decision to abandon Space Act Agreements (SAAs) and return to the Federal Acquisition Regulation (FAR) system as a major setback. The rapid progress of these companies is seen to be, in large part, the result of SAAs, and reinstituting the outdated, inefficient bureaucracy of the FAR Part 35 contracting vehicle will likely undermine much of the hard-won cost savings and speed of development.

by **Franz Newland** and **J. Paul Douglas**

# Space resources

This year marked some significant changes in the NASA in-situ resource utilization (ISRU) project. The first change was renewed interest in development of the RESOLVE (regolith and environment science and oxygen and lunar volatile extraction) experiment to characterize lunar polar ice/volatiles and perform subscale oxygen extraction from regolith. The second change was the transition of technology development from the ETDP (exploration technology development program) to the ETDDP (enabling technology development and demonstration program) at the start of FY11.

*Students at the University of Texas at El Paso investigated self-sustained combustion of JSC-1A lunar regolith simulant mixed with magnesium on a reduced gravity aircraft flight.*

Development work on the third generation of RESOLVE began in June. The goal is to build a prototype unit that meets the expected lunar environmental and flight requirements by 2014. RESOLVE is being developed by four NASA centers (Kennedy, Johnson, Ames, and Glenn) in collaboration with the Canadian Space Agency (CSA) and its contractors: the Northern Center for Advanced Technologies, Neptec, and Xiphos. The Phase I effort will develop a RESOLVE unit that will undergo analog field testing in 2012, but the unit will meet as many of the lunar environment and mission requirements as possible. Phase II will refine the design to operate under simulated lunar environmental (vacuum and temperature) conditions.

The RESOLVE Phase I unit completed its preliminary design review (PDR) in May and its critical design review (CDR) in July. The unit will be tested on both a NASA and CSA rover, including an upgraded version of the Juno rover demonstrated at the 2010 analog field test on Mauna Kea. The analog field test will stress both the hardware and mission operations by simulating two different five-to-seven-day missions to the lunar poles with remote operations from both NASA and CSA centers.

Although ETDP focused solely on supporting lunar exploration and the Constellation program, the ETDDP scope includes other destinations of potential interest for human exploration, such as Mars and near-Earth objects. Several technologies to extract oxygen from regolith were successfully demonstrated in two previous analog field tests, so two new efforts were initiated over the past year to support the broader goal of exploring multiple destinations.

The larger of the new efforts is the Marco Polo project, which integrates atmospheric and soil-based ISRU with fuel cell power and cryogenic/gas storage to simulate a possible Mars ISRU demonstration on a 3-m-diam. lander. Marco Polo completed its PDR in April and its CDR in September with the goal of a field test in NASA Johnson's Mars 'rockyard' in August 2012. The other new effort is trash/waste processing to manufacture fuel.

Honeybee Robotics developed the LunarVader drill to obtain subsurface water-ice and mineral samples. The LunarVader was successfully tested to a depth of 1 m in a vacuum chamber with various formations, including a water-saturated lunar regolith simulant (JSC-1A) at -80 C, pure water-ice, and rocks. The system was also field tested in the lunar analog site on Ross Island near Antarctica. During the vacuum chamber and field testing, the LunarVader demonstrated drilling to 1 m in approximately 1 hr with roughly 100-W power and less than 100-N weight on bit. This corresponds to a total drilling energy of approximately 100 W-hr.

The NASA-sponsored Center for Space Exploration Technology Research at the University of Texas at El Paso (UTEP) demonstrated self-sustained combustion of JSC-1A lunar regolith simulant mixed with magnesium. This process could potentially be used to produce structural materials on the Moon. In June, UTEP's student team also investigated this process onboard reduced-gravity research aircraft at NASA Johnson.

by **Robert Gustafson**

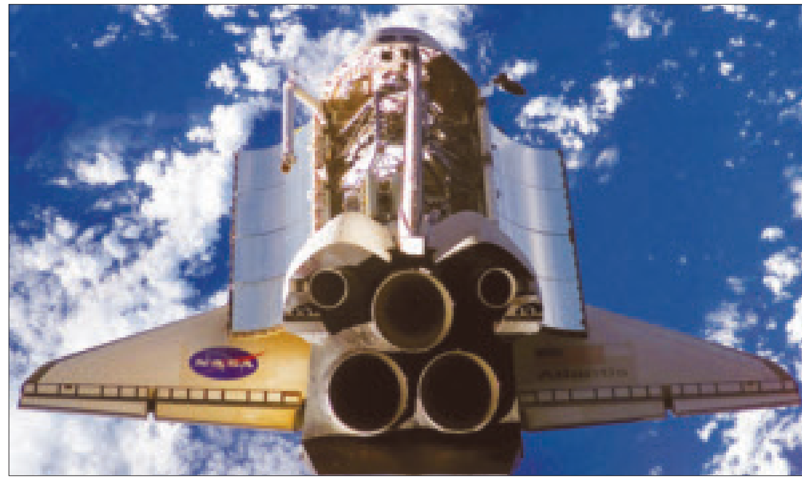
# Space systems

This proved to be a year of change: America's most recognizable human spaceflight program ended, U.S. commercial companies were developing and testing new cargo and crew space transportation designs, and a paradigm shift was under way for how payloads would find rides into orbit. New technologies were launched to demonstrate future military communications capabilities, and an exciting mission to our solar system's largest planet began.

After 135 missions spanning just over 30 years, NASA's space shuttle program came to an end when the orbiter Atlantis landed on July 21. The agency has moved forward with the engagement of private industry for the next generation of space transportation capabilities. SpaceX and Orbital Sciences achieved major milestones under NASA-funded COTS (commercial orbital transportation system) program Space Act Agreements (SAAs) for the development of commercial cargo transportation space systems. In April, the agency issued funded SAAs for the development of commercially provided human spaceflight systems under the CCDev (commercial crew development) program. Boeing, Sierra Nevada, SpaceX, and Blue Origin shared $270 million in CCDev funding to refine their concepts for transporting NASA crewmembers to and from space.

Each company is providing a distinctly different type of spacecraft design under the CCDev effort. Boeing's CST-100 concept is a traditional capsule configuration similar in shape to the Apollo design. SpaceX's Dragon has adopted a blunt cone ballistic capsule design similar to its cargo vehicle. Sierra Nevada's Dream Chaser is pursuing a spaceplane configuration derived from NASA's HL-20 program, and Blue Origin is employing a biconic reentry spacecraft design. The companies are expecting to provide crew transportation services in the 2014-2016 timeframe.

In September, the TacSat-4 satellite was launched from the Kodiak Launch Complex on a Minotaur-IV. The Navy-led joint tactical microsatellite mission features a 12-ft-diam. deployable antenna with 10 UHF channels battlefield commanders can use with a multitude of existing communications systems. Placed in a 'low highly elliptical orbit,' TacSat-4 can provide long dwell times over intended theaters of operations to enable communications on the move, blue force tracking, and data exfiltration.



*After 135 missions spanning just over 30 years, NASA's space shuttle program came to an end when the orbiter Atlantis landed on July 21.*

Also in September, the commercially hosted infrared payload (CHIRP) was launched as part of the SES-2 telecommunications satellite on an Ariane 5 rocket out of Kourou, French Guiana. This marked the first time the USAF has integrated a payload into a commercial satellite. The expectation is that CHIRP will validate a new approach for reducing program cost and schedule by hitching a ride as part of a host spacecraft. The mission, developed by a government-industry team, is set to demonstrate and mature wide-field-of-view infrared imaging technologies for future missile warning/defense, intelligence gathering, and battlespace awareness missions.

Going beyond Earth orbit, the Juno mission kicked off its five-year journey to the largest planet in our solar system. Launched in August on an Atlas V-551, the spacecraft is due to arrive at Jupiter in July 2016 to conduct a one-year study of the massive planet. A host of scientific payloads on Juno will examine the composition of Jupiter's upper atmosphere, peer down to determine the level of water and ammonia in the deep atmosphere, search for the existence of a solid core, and map the planet's magnetic and gravity fields. Through observation of the magnetosphere scientists seek to understand how the planet's magnetic fields interact with the atmosphere to create its unique weather phenomena.

Juno is the second spacecraft developed under NASA's New Frontiers program. The first was the Pluto New Horizons mission, launched in 2006 on a mission to fly by Pluto in 2015 and go on to explore the Kuiper Belt. As of October, New Horizons was traveling at 15.5 km/sec just beyond the orbit of Uranus.

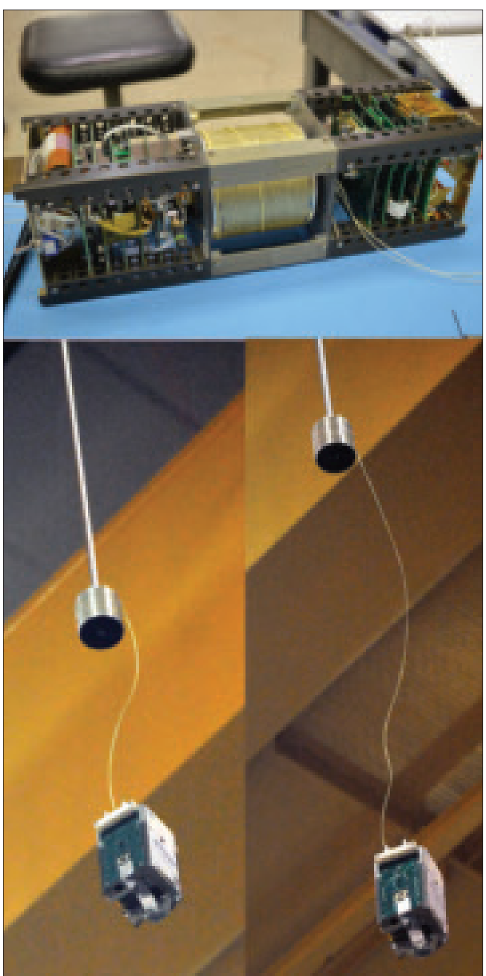
by **Jim Baker**

# Space tethers

This year the space tethers community has continued to prepare several upcoming flight experiments and to develop new technologies and applications.

The Naval Research Laboratory is nearing completion of two tethered satellite systems to demonstrate electrodynamic-tether (EDT) propulsion in LEO. TetherSat, being built in conjunction with the Naval Academy, will test deployment of a 1-km tether connecting two 1.5-U CubeSat end masses. The tether electrodynamic propulsion CubeSat experiment (TEPCE) will perform orbit maneuvers. Extensive testing this year included tether deployment experiments in vacuum chambers and by free fall in air.

An assembled TEPCE satellite shows the tether spool in the middle (top) and stacer deployment test in free fall (bottom left and right).



These tests validated tether deployment driven by a long-stroke spring called a stacer, which pushes the end masses apart at 4 m/sec and then stabilizes deployer attitude. With body-mounted solar cells and tungsten filament cathodes, TEPCE will be able to change its orbit altitude by 1 km per day. Both TEPCE and TetherSat will carry cameras and GPS receivers. The cameras will document, and the GPS receivers will help characterize the tether deployment as well as subsequent tether dynamics. TEPCE will also carry special plasma electron density sensors that will measure the ionospheric plasma. Launch of TetherSat and TEPCE by the Air Force's satellite test program is expected in 2012.

STAR (Star Technology and Research) and Tether Applications continued development of their electrodynamic debris eliminator (EDDE) concept to actively remove large debris objects from LEO using lightweight nets deployed from the ends of a space tether. A cost analysis performed for NASA's Office of the Chief Technologist determined that EDDE could remove from orbit in 10-12 years all of the largest LEO debris objects, totaling 2,000 tons, for about $7 million a year for each of the 12 members of the Inter Agency Debris Committee. Using data from the NRL TEPCE program, a Mini-EDDE is being designed for an orbital flight demonstration, perhaps by 2014.

The European Commission's seventh framework program, FP7, awarded funding to the bare electrodynamic tethers project to carry out EDT technology development for the mitigation of orbital debris through passive electrodynamic propulsion. Led by Polytechnic University of Madrid, the team of universities (University of Padova, Colorado State University), research institutes (ONERA–Toulouse, DLR–Bremen, and Fundacion Tecnalia) and companies (emxys) is performing trade studies and performance analysis; studies of plasma-tether interaction; orbit and tether dynamics and control; tether survivability; and construction of prototypes of key components.

At the University of Glasgow work continues on mission architectures for two-way Earth-Moon payload exchange using motorized momentum exchange tethers. This project has proven that the concept is feasible through rigorous astrodynamical analysis. Glasgow is also a major participant in the ESA REXUS (rocket experiments for university students) sounding rocket project known as *Suaineadh* (Scottish Gaelic for twisting), along with KTH Stockholm and Strathclyde University, Glasgow. The project is due to launch a test web from a payload deployed by the REXUS sounding rocket in spring 2012.

An Air Force Office of Scientific Research-funded team from Penn State, University of Michigan, and Tethers Unlimited has continued its research on the use of energy-harvesting EDT systems. Such systems can generate power and propulsion on spacecraft using EDTs by storing energy in and deriving energy from the 'orbital battery.' Detailed simulations show that large satellites can harvest as much as kilowatts of power and have round-trip efficiencies of better than 75%. CubeSat-based systems could harvest tens of watts, but efficiencies are highly dependent on the plasma contactor and tether resistance. Femtosats, such as ChipSats, could benefit by EDT systems that would enable them to overcome aerodynamic drag and to maintain orbit without the need for expendable propellant.

by **Sven G. Bilén** and the **AIAA Space Tethers Technical Committee**

# Space transportation

NASA concluded the space shuttle program with the final flights of its three orbiters. The agency has also announced the Space Launch System (SLS) to initiate a heavy-lift launch capability for both manned and unmanned missions.

Discovery (STS-133), Endeavour (STS-134), and Atlantis (STS-135) were launched to the ISS. These flights delivered the alpha magnetic spectrometer and provided a logistics surplus of supplies.

NASA decided to use Orion as the multipurpose crew vehicle and to initiate an SLS program to provide the basis for future human exploration beyond LEO.

The United Launch Alliance (ULA) has had a busy year. An Atlas 5 launched the military's X-37B in March, the NROL-34 spacecraft in April, SBIRS GEO 1 (the military's first space-based infrared system geosynchronous satellite) in May, and NASA's Juno spacecraft to Jupiter in August. A Delta II rocket launched Argentina's SAC-D satellite with the Aquarius instrument for NASA, the GRAIL mission for NASA, and the NPP weather satellite for NASA/NOAA along with six CubeSats. A Delta IV launched the NROL-27 satellite and the Air Force's second Block 2F navigation satellite for the GPS. Finally, a Delta IV-Heavy launched the NROL-49 payload. ULA also signed a space act agreement with NASA to collaborate on human rating for crewed flights.

The Air Force Minotaur 1 launched the ORS 1 satellite payload, while the Minotaur 4 launched the TacSat 4 demonstration satellite for the military ORS office.

Orbital Sciences' Taurus rocket failed to orbit NASA's Glory Earth observation satellite from Vandenberg AFB, and Sea Launch returned to service with the launch of a telecommunications satellite for Eutelsat.

The Johannes Kepler ATV-2, launched by an Ariane 5 to the ISS in February, docked with the station to deliver supplies and raise the station orbit by 37 km. The ATV-2 launch was the first this year by the Ariane 5, followed by four other Ariane launches through September. Work continues on the improved version of the Ariane 5 with a new restartable cryogenic upper stage equipped with a Vinci engine.

The Soyuz launch pad was completed in French Guiana, and the first Soyuz flight from the site took place on October 21. It successfully carried into orbit the first two Galileo operational satellites for the European global positioning system. The small Vega launcher and its facilities in French Guiana are also in final preparation for a launch early next year.

Russian launch activity included two Proton launches by International Launch Services, eight Soyuz launches (four Progress ISS supply capsules, two manned capsules to the ISS, and two unmanned payloads to orbit), one Rockot launch, and two Zenit launches. The loss of one of the Progress capsules may affect the manned status of the ISS for a while.

Other launches included six for China's Long March, two for India's PSLV, one for Japan's H-2B, which carried the HTV-2 supply vehicle to the ISS, and another for Japan's H-2A.

Significant progress continued in NASA's efforts to jump-start a commercial space industry. Under NASA Space Act agreements, SpaceX and Orbital Sciences made significant progress toward cargo delivery to the ISS starting in 2012. Blue Origin (New Shepard), Sierra Nevada (Dream Chaser), Space Exploration Technologies, or SpaceX (Falcon 9/Dragon), and Boeing (CST-100) were all funded to develop commercial crew systems. In addition, NASA selected seven companies to integrate and fly technology payloads on commercial suborbital reusable platforms that carry payloads near the boundary of space, including Armadillo Aerospace, Up Aerospace, Near Space, Masten Space Systems, Virgin Galactic, Whittinghill Aerospace, and XCOR.

Propellant depots are an emerging concept. Depots can potentially remove the need to launch with all the fuel required to complete an entire mission—in turn allowing launch vehicles to lift more hardware into space.

*With the predawn landing of Atlantis returning from its STS-135 mission on Thursday, July 21, the space shuttle era came to a close. Credit: NASA.*

by **Carl Ehrlich** and the **AIAA Space Transportation Technical Committee**

# Weapon system effectiveness

by **James D. Walker** and **David Lyman**

An analysis of alternatives (AOA), as defined by the Air Force Materiel Command's Office of Aerospace Studies in its *Analysis of Alternatives Handbook*, is "an analytical comparison of the operational effectiveness, cost, and risks of proposed materiel solutions to gaps and shortfalls in operational capability. AOAs document the rationale for identifying and recommending a preferred solution or solutions to the identified shortfall(s)." AOAs ensure that a weapon system is the right one to perform a required task in a cost-efficient manner. Typically, operational effectiveness analysis (a capabilities-based analysis), in conjunction with a life-cycle-cost analysis, is performed during the AOA.

*Solution choices and performance measures are challenging in the case of replacing the Humvee: refurbish and upgrade, or build new ones.*

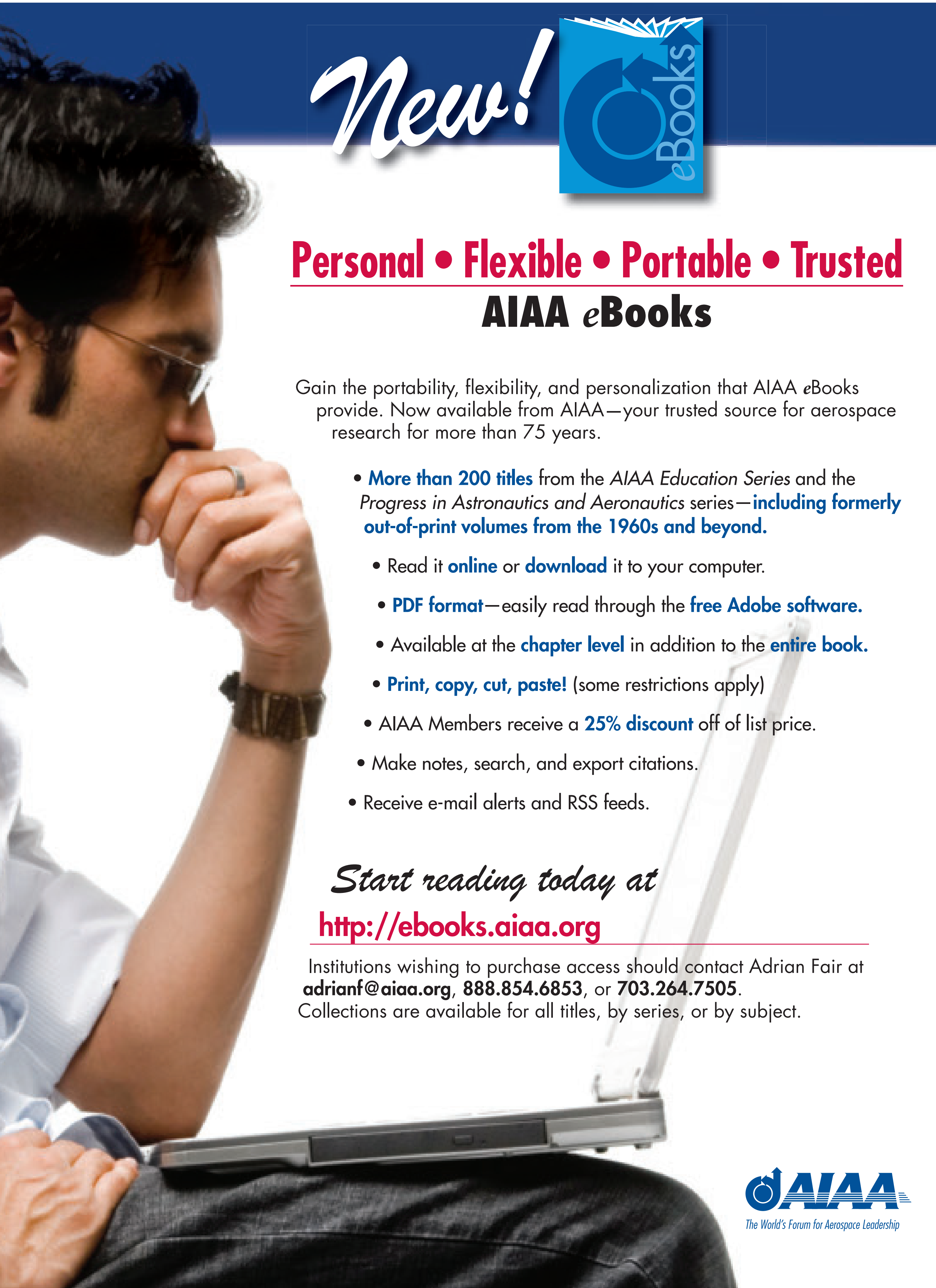
The AOA's framework is critical to finding the best solution, regardless of the type of weapon system. For instance, if a set of engineering requirements is specified at the beginning of an AOA, the likely result is confirmation that the suggested weapon system is the only one that meets those requirements. The AOA, in some sense, needs to be based on the notion of a desired effect, with the means of achieving that effect left open. With performance defined in this manner, different types of weapon systems can potentially provide the solution.

Risk is a key component of the AOAs. In the risk analysis, teams of people think through the defined scenarios. These teams estimate the probability of failure of the weapon system and determine the consequences of failure, which range from not delivering ordinance to loss of soldiers' lives. The risks from all the proposed alternatives are compared. This process allows not just a comparison of intended-use scenarios and associated costs, but also the detailed cross comparison of not-optimum to worst-case scenarios, their likelihood, and their consequences.

AOAs differ in 'desired effects.' For example, the RAND-led AOA for midair refueling looked at many alternatives, including upgrading the KC-135 fleet, designing and building totally new military tankers, using variants of newly purchased or used commercial aircraft as tankers, and using unmanned and commercial refueling. In this case there is an existing fleet of tankers and the question is how much it costs to maintain and upgrade them (including fuel efficiency) vs. going to different planes. The AOA concluded new commercial-based tankers were best. All options were able to refuel in air, so the deciding factor was cost. This AOA determined the best weapon system with its associated operational requirements and timetable; then it was put out for bid (that is, the AOA is not to compare contractor bids).

The solution choices and performance measures become more difficult and challenging in the case of replacing the Humvee. One approach is to refurbish and upgrade existing vehicles. Another is to build new Humvees of essentially the same design as the current versions.

A third option that was being pursued by the Army and Marines, and is currently facing cancellation, is the Joint Light Tactical Vehicle (JLTV), a new replacement vehicle. Though superficially this may appear similar to the tanker question, another issue arises for this ground vehicle: crew survivability. The JLTV is intended to be substantially more survivable, based on experience in Iraq and Afghanistan and with the MRAP (mine-resistant ambush protected) vehicles. Thus, it is not just a question of cost. It is also a question of capability and protection. The AOA, completed this year, did a detailed scenario development and risk analysis, where the probability and consequences of failure were explicitly spelled out. It was necessary to go through the scenarios and ascertain their likelihood based on current doctrine and possible engagements. The AOA concluded that the JLTV program is the best option to fill the capability gaps.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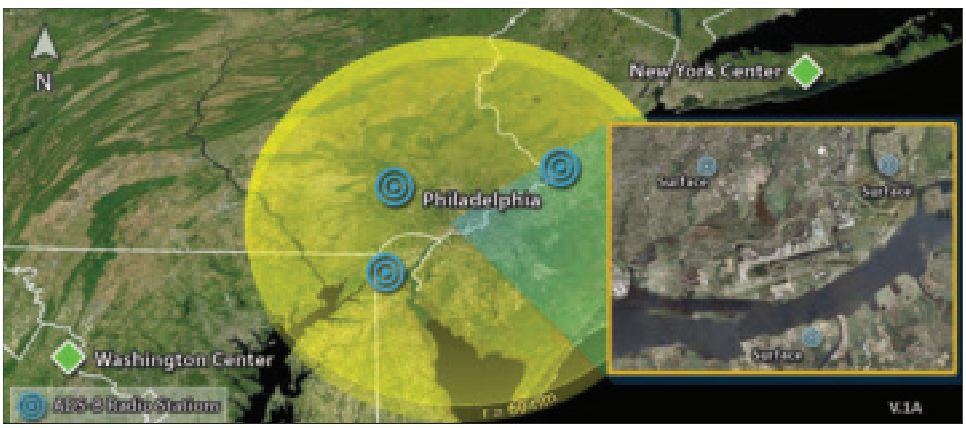
# Aerospace traffic management



*The FAA released this map of ADS-B sites in Philadelphia in 2010.*

This year has brought a mix of positives and negatives for aerospace traffic management. The modernization of the air transportation system, called NextGen in the U.S. and SESAR in Europe, saw an early victory with the initial deployment of ADS-B (Automatic Dependent Surveillance-Broadcast) in February starting at Philadelphia. This installation allows ADS-B Out messages from appropriately equipped aircraft to be collected on the ground and used for surveillance, providing considerably more accuracy than either conventional terminal or enroute radar. In addition, for aircraft equipped with ADS-B In, you get to see the actual report from the aircraft, and those with the TIS (traffic information service) capability see all traffic reports broadcast from the ground stations. This is certainly a plus and a great start for the implementation of NextGen.

Installation of the enroute modernization program (ERAM) has begun to slip due to software issues. DOT Inspector General Calvin Scoville stated, "FAA now plans to complete ERAM in 2014—a schedule slip of four years—with the next major milestones focused on getting the Salt Lake City and Seattle sites fully operational. However, FAA and its contractor plan to add new capabilities while attempting to resolve problems identified in earlier software versions, which could cause further schedule delays. Updated software releases have already exhibited new problems, including interfacility interface issues that lock up the system, and a significant software failure that resulted in Seattle falling back to the legacy system for several weeks." ERAM is one of the automation platforms that will host early NextGen functionality.

This year Congress was unable to pass the FAA reauthorization bill that expired in 2007, and instead passed several continuing resolutions to keep the FAA in operation. However, near the end of the summer session, Congress failed to pass a continuing resolution. This resulted in the cessation of noncritical operations at the FAA and the furlough of all nonessential personnel, adding further uncertainty to planning for future NextGen development and progress.

Responding primarily to the domestic economic slowdown experienced in the past several years, the Joint Planning and Development Office (JPDO) conducted an analysis to identify a target endpoint for NextGen 2025, based on the current implementation path and projected costs, benefits, and risks. The JPDO subsequently released an interim report on the vision for NextGen 2025 based on this analysis, called "Destination 2025."

This year the JPDO also conducted several important studies related to NextGen. One was the development of scenarios for trajectory based operations (TBO) in NextGen, which continued into a second phase that will enhance the TBO concept and develop a road map for TBO in the NextGen environment.

The results of another first-phase study of Flight Prioritization (FP) were released in January. FP is the study of mechanisms to be used within NextGen to adjudicate contentions for NextGen resources between multiple flights through equitable or other means as directed by policy. A second phase of the FP study is planned for the first quarter of FY12.

Additional topics analyzed by the JPDO this year and slated to continue into 2012 include identification of unmanned aircraft systems research challenges and development of a research road map; synchronization of weather data requirements and translation efforts; concept development for integrated surveillance; and completion of the concept definition for the roles of airline and flight operations centers.

by **James Cistone**
and **Edward J. Stanton Jr.**

# Directed energy systems

The emphasis in development of directed energy weapon systems shifted toward tactical systems in Dept. of Defense programs. The Airborne Laser (ABL) platform was used this year as a testbed and successfully flew numerous missions in that capacity without engaging in high-power tests. Significant advances were made in different types of COIL (chemical oxygen iodine laser) efficiencies promising output performance increases of an order of magnitude; the ABL uses a COIL as its high-power laser source.

The Office of Naval Research (ONR) free electron laser program faced termination due to language in the FY12 Senate Appropriations bill, which directs the Navy to “develop a broader affordable strategy on laser systems” and urges planning for a “shoot-off” between tactical shipboard laser concepts. The Navy continued pursuit of tactical laser concepts through the ONR maritime laser demonstrator and the Naval Sea Systems Command (NAVSEA) LaWS (laser weapon system) concepts. DARPA pursued acquisition of the 100-kW-class solid-state HELLADS (high energy liquid laser area defense system) for potential application to the Air Force ELLA (electric laser on a large aircraft) program. The Air Force Research Laboratory progressed with its Boeing/Raytheon-K-Tech RF/HPM (radio frequency/high power microwave) demonstration project, CHAMP (counter-electronics high power microwave advanced missile project). The Army high energy laser tactical demonstrator was completed and delivered to Army Space and Missiles Defense Command and is scheduled for testing at White Sands Missile Range beginning this winter. The High Energy Laser Joint Technology Office continued its robust electric laser initiative developments with different approaches and concepts from Lockheed/Acculight, Raytheon, Northrop Grumman, General Atomics, and Boeing.

Tactical laser weapon systems are of interest to the Army and Navy because they reduce usage of costly missiles and hit targets almost instantaneously. ONR program officer Peter Morrison told *Inside the Navy* on Sept. 14 that the 2000 attack on the USS Cole highlighted the need for a weapon to defend against one or a swarm of small boats, especially when a naval vessel is in a posture where it cannot rely on its arsenal of kinetic weapons.

*A military truck will carry a Boeing-built laser beam control system for the Army's high energy laser technology demonstrator program.*

Only recently have solid-state lasers reached strengths of hundreds of kilowatts of power—enough to destroy a vehicle or negate an incoming warhead. The solid-state laser weapon system the Navy envisions could be installed on combatant-class ships of all sizes, according to Morrison. It could also shoot down threatening missiles and aircraft and would be safer and more effective than previous laser weapons.

ONR and Northrop Grumman demonstrated that capability in April; the maritime laser demonstration program met its goal. A decommissioned Spruance-class destroyer shot its target, which caught fire despite the sea spray, waves, wind, and other obstacles. The Naval Sea Systems Command has also overseen two successful demonstrations of solid-state laser weapons. NAVSEA's LaWS has successfully tracked and destroyed five UAVs from the ground. This summer NAVSEA and BAE Systems' Mk 38 tactical laser system distinguished enemy small boats from neutral traffic and successfully tracked and destroyed its targets.

NASA continued sponsoring and conducting research into nonweapons aspects of directed energy systems involving beamed energy propulsion. BEP vehicles would be driven by power beamed from remote, reusable, long-range sources including high-power lasers or microwaves. Launch vehicles driven by BEP would be smaller, lighter, faster, and more efficient than any currently existing means of space transportation. This year a NASA report by John Cole of NASA Marshall concluded that BEP technology is feasible and currently stands at TRL 2 (technology readiness level 2); in August NASA issued a request for proposals for such systems.

by **James A. Horkovich**

# Energy optimized aircraft and equipment systems

As environmental concerns come to the forefront and the pressure to reduce costs rises, optimizing energy use in aircraft has become increasingly important. That trend, combined with the fact that more electric aircraft architectures are now a reality, points to a bright future in this field.

The Pipistrel was the ultimate winner of the Green Flight Challenge.

The 787, with its more-electric environmental control system and wing deicing system, is not only flying, but is certified and has been delivered to its first customer. Boeing received certification for the 787 Dreamliner from the FAA and the European Aviation Safety Agency in August of this year. And the Rolls-Royce Trent 1000 bleedless engine also received ETOPS (extended twin engine operations certification) from the FAA in May, which paved the way for the first Dreamliner customer delivery to All Nippon Airways on September 26.

The Joint Strike Fighter empennage electrohydraulic actuators have further demonstrated their capability this year even in the harsh conditions of catapult launch testing. The F-35C took to the sky in July launched by a steam catapult for the first time. The F-35C is the carrier variant of the F-35 JSF, and has larger wing surfaces and reinforced landing gear for slower catapult launch and landing approach speeds. However, it still uses the same more-electric actuators as the other variants.

The Air Force INVENT (integrated vehicle energy technology demonstration) research program is now entering Spiral 2 of development in an effort to step beyond more-electric systems and to set energy optimization goals at the vehicle level. This effort provides national leadership for addressing the critical technical challenges of new design methodologies and is optimized to take full advantage of all the benefits of more-electric aircraft architectures.

Similarly, research into aircraft energy management continues across the Atlantic under the European Clean Sky program. The latest list of topics for this program, which was released over the summer, includes several relating to 'Systems for Green Operations' ranging from power electronics technologies to jam tolerant electric actuators.

The A380, with its electrical thrust reversing system and electric backup actuators, has been in service now for several years. Its only incident on record, on a Qantas flight in November of 2010, was traced to an engine oil leak and was not related to its more electric systems.

As more-electric aircraft architectures continue to prove themselves in operation, the progression to an all-electric aircraft becomes a tantalizing goal. The first taste of this came with this year's Comparative Aircraft Flight Efficiency Foundation Green Flight Challenge competition, which was sponsored by Google and took place in September.

The Green Flight Challenge is a flight competition for quiet, practical, green aircraft. The original 13 entrants, which encompassed a variety of green approaches including biodiesel, hydrogen, and electricity, have now been reduced to five. Of these five remaining aircraft, three are electrically driven and a fourth one has a hybrid gas/electric system. While all of these aircraft are small, they will be demonstrating the potential of electric technologies to be instrumental in the development of the quiet, efficient, green aircraft of our future.

by **Elena Garcia**

# Hypersonics technology and aerospace planes

*Skylon's SABRE engines use liquid hydrogen combined with oxygen from the air at altitudes of 26 km and speeds of up to Mach 5. Credit: Reaction Engines.*

The first orbital flight of the X-37B was launched on an Atlas V rocket in April 2010. The spacecraft was placed into LEO for testing. As scheduled, the X-37B deorbited, reentered Earth's atmosphere, and landed at Vandenberg AFB on Dec. 3, 2010.

A second X-37B was launched aboard an Atlas V on March 5 and remains on orbit. Its mission, as described by military officials, was to test new space technologies.

The second test flight of the X-51 took place in June. However, the flight over the Pacific Ocean ended early because of an inlet unstart event after being boosted to Mach-5 speed. The flight data from the test is being investigated. A B-52 released the X-51 at an approximate altitude of 50,000 ft. The X-51's scramjet engine lit on ethylene, but did not properly transition to JP-7 fuel operation.

A second test flight of the experimental Falcon Hypersonic Technology Vehicle 2 traveling at Mach 20 ended prematurely when the aircraft failed and stopped sending back real-time data to engineers and scientists who were monitoring the mission. The aircraft plunged into the Pacific Ocean. This was the second and last scheduled flight for the Falcon program, which began in 2003. For the test, the Falcon was launched from Vandenberg AFB aboard a Minotaur IV made by Orbital Sciences.

The NASA Hypersonics Project has initiated testing of a large-scale TBCC (turbine-based combined cycle) propulsion system inlet in the NASA Glenn 10x10-ft Supersonic Wind Tunnel.

A detailed ESA technical assessment of the U.K. Space Agency's proposed Skylon spaceplane concluded that there are no significant barriers that would prevent successful continued development of the craft and its synergistic air-breathing rocket engine, or SABRE. The report states that "Success on future engine test would mean a major breakthrough in propulsion worldwide. The engine and vehicle can be developed with today's current technology." Reaction Engines, the developer, will conduct an important demonstration of the engine's key precooler technology later this year.

The Australian Scramspace 1 (scramjet-based access-to-space systems) project is the first step on the road to what could be, for the country's nascent space business projects, an affordable, reliable, and repeatable launch system based on combined air-breathing and rocket propulsion. Aimed at free-flight tests of a Mach-8 scramjet, Scramspace 1 has passed its preliminary concept development phase and is on track for launch in October 2012.

A spacecraft control flap designed for the superheated hypersonic fall through Earth's atmosphere has come through testing in the world's largest plasma wind tunnel to be ready for its first flight next year. This flap and its advanced sensors are destined to fly on ESA's EXPERT (European experimental reentry testbed), a blunt-nosed capsule being launched next spring on a Russian Volna rocket to gather data on atmospheric reentry. EXPERT carries experimental side flaps to help show that they can steer larger ESA reentry vehicles such as the IXV intermediate experimental vehicle in 2013.

The test flap, which is identical to the flight version, is made from heat-resistant ceramics. Its instruments include a miniature infrared camera provided by RUAG Space Switzerland, and pressure and high-temperature sensors developed by both the German Aerospace Center (DLR) and the Italian Aerospace Center (CIRA) to investigate shock wave/boundary layer interaction phenomena.

These tests took place at Italy's Scirocco plasma wind tunnel at CIRA. One of the few sites worldwide where such testing is possible, it is named for the hot Mediterranean wind and operated by the CIRA aerospace research center. Its arc heater was taken up to 10,000 C with 38 MW of electricity, creating a plasma flow seven times the speed of sound and bringing the temperature of the flap up to 1,200 C.

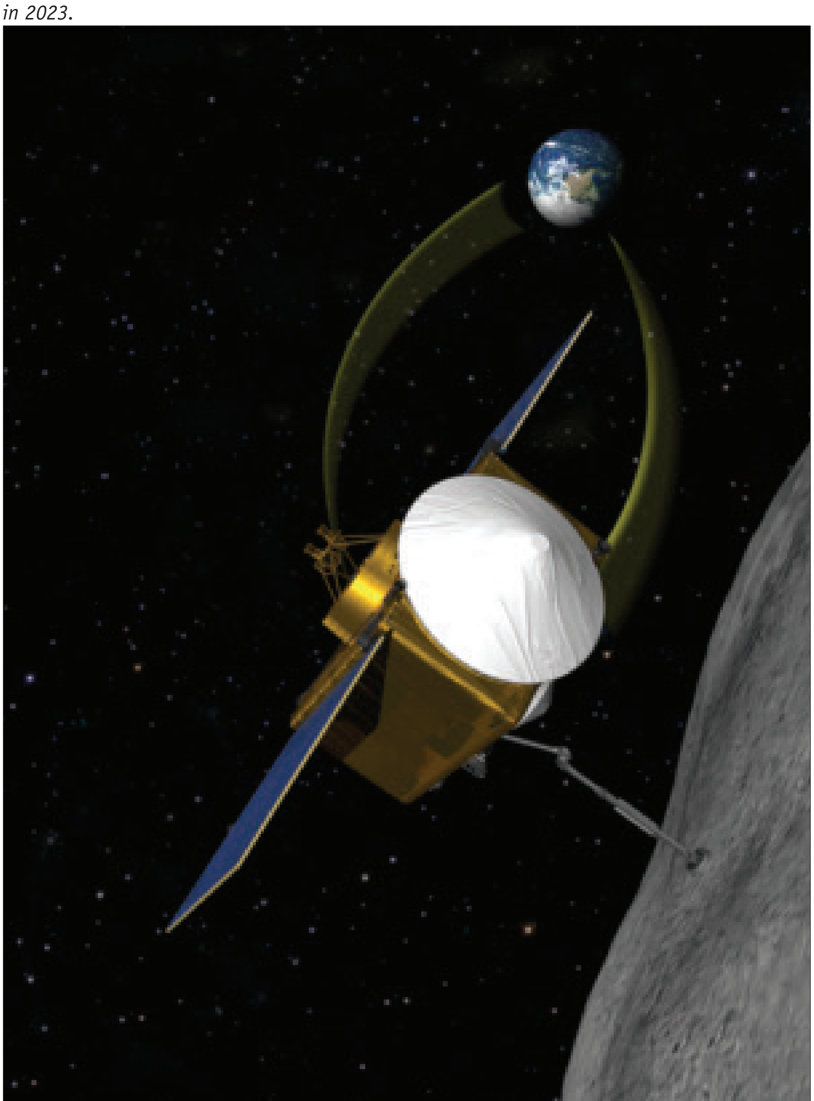
by **Carl Ehrlich** and the **AIAA Hypersonics Technology and Aerospace Planes Program Committee**

## Space environmental systems

Missions to asteroids, Earth orbit, and the Moon highlighted the activities of the interplanetary space community this year. Technical problems in the NASA Curiosity rover have the potential to create a two-year delay in the launch to Mars.

The NASA New Frontiers program picked the OSIRIS-REx (origins-spectral interpretation-resource identification-security-regolith explorer) to launch to asteroid 1999 RQ36 in 2016 on a mission that would return samples in 2023. The main purpose of the mission is to "shed light on the conditions of the infant solar system and how life emerged." NASA Administrator Charles Bolden said, "This is a critical step in meeting the objectives outlined by President Obama to extend our reach beyond low Earth orbit and explore into deep space."

*OSIRIS-REx will travel to asteroid 1999 RQ36 in 2016 on a mission that would return samples in 2023.*



The University of Arizona is overseeing the mission with support from private industry and from NASA Goddard. This effort is an example of dual mission focus for the agency. Once the primary mission is completed and OSIRIS-REx has sent back asteroid material, the spacecraft itself will be redirected into a new solar orbit and will then be available to perform another mission in the future.

The Curiosity Mars rover was over budget and behind schedule at midyear. The NASA inspector general faulted project managers for routinely underestimating costs and calculated that adding an extra $44 million to the development budget may be necessary to avoid another delay or cancellation. The $44 million the report calls for is already on reserve and is included in the overall $2.5-billion price tag. The possibility that the rover's drill bit could contaminate the rock and soil samples it obtains and undermine the primary mission has been one of the major causes for concern. The mission would likely spend $22 million from the reserves already set aside by NASA's Science Mission Directorate. A two-year delay in Curiosity's launch to Mars would significantly impact rover missions on the planet.

A Delta 2 rocket launched the SAC-D/Aquarius satellite into LEO in June on a mission to track changes in the amount of salt in the upper levels of the world's oceans. This was the first of five United Launch Alliance missions scheduled for NASA this year. The Aquarius salinity sensor is a key success for the agency's climate science program and will deliver the most detailed map ever made of the salt content of the Earth's oceans.

A United Launch Alliance Delta II rocket carried the twin GRAIL (gravity recovery and interior laboratory) spacecraft into space in September on a mission to the Moon. GRAIL is taking its next big leap into deep space exploration with a mission that involves the formation flying of two spacecraft. NASA's educational outreach programs are also part of the effort, which amounts to the start of a revolution in planetary science missions. Students will be able to image spots on the Moon. Former NASA astronaut Sally Ride's educational program is heading the effort, with 600 teachers and students registered for the activity at www.moonkam.ucsd.edu.

## Space exploration

When the final mission of space shuttle Atlantis ended on July 21, a remarkable 30-year era in human spaceflight came to a close. The shuttles flew 135 times, ferrying 355 astronauts into orbit, completing assembly of the ISS, docking with Russia's Mir space station, servicing the Hubble Space Telescope, and conducting numerous research experiments that have vastly expanded our knowledge and our spaceflight capabilities. This year's three shuttle missions delivered the Alpha Magnetic Spectrometer, a robotic refueling experiment, and supplies to the ISS. As the shuttle orbiters head off to museums, it is also the beginning of a new era that will carry humans far beyond Earth.

To enable deep space human exploration, NASA proceeded with development of the Space Launch System (SLS) and the Orion multipurpose crew vehicle (MPCV). In September, the agency announced the design configuration for SLS, the new heavy-lift launch vehicle authorized by Congress in 2010. The initial version will be capable of launching 70 metric tons into orbit, with future versions evolvable to 130 metric tons. To minimize development costs, the new rocket will use shuttle-derived hardware. The core stage will be based on the shuttle external tank, and will be powered by an expendable version of the shuttle main engines. For initial flights, shuttle-derived solid rocket boosters will be attached to the core stage, and a competition is planned to select advanced solid or liquid boosters. A J2-X engine upgraded from the J2 engine used on the Saturn V will power the SLS upper stage.

Testing of components for the SLS is under way. The J2-X engine was fired for the first time at NASA Stennis, and ATK conducted a third test of the five-segment solid rocket motor. The initial flight of SLS is targeted for late 2017.

A series of water landing splash tests of the Orion capsule took place at NASA Langley in a new hydro impact basin.

Lockheed Martin completed acoustic testing of the Orion MPCV capsule and launch abort system. A series of water landing splash tests of the capsule took place at NASA Langley in a new hydro impact basin. Navigation sensors for Orion's autonomous rendezvous and docking system were tested in orbit on the STS-134 mission. Construction of the first space-bound Orion capsule began at the Michoud Assembly Facility.

Space-X launched its Dragon capsule on December 8, 2010, and became the first company to recover a capsule reentering from orbit. NASA awarded $270 million to four companies to continue the development of commercial rockets and spacecraft designed to fly astronauts to the ISS. In August, a launch failure of Russia's Soyuz rocket threatened to cause a situation in which the crew would have to abandon the ISS temporarily, and highlighted the need for multiple crew transportation options in the post-shuttle era.

NASA signed a cooperative agreement with the nonprofit Center for Advancement of Science in Space to operate the ISS as a national laboratory for basic and applied research, to stimulate STEM (science, technology, engineering, and mathematics) education, and to generate economic benefits.

Exploration technology development activities included teleoperation of Robonaut 2 on the ISS, testing of portable life support system components for an advanced spacesuit, demonstration of a prototype deep space habitat in desert field tests, and industry studies for cryogenic propellant storage and solar electric propulsion flight demonstration missions.

The 14-nation International Space Exploration Coordination Group issued the first iteration of a global exploration road map that outlined a common strategy for deep space exploration. It identifies two alternate pathways to Mars: humans first exploring either the Moon or near-Earth asteroids. Each pathway is defined by a notional mission scenario describing a logical sequence of human and robotic missions that will cover a 25-year period.

by **Chris Moore**

# Unmanned systems

This was another year in which the discussion of unmanned aircraft systems (UAS) in the U.S. was dominated by regulatory issues at home and military policy issues abroad.

Rising demand from civil and public users alike to deploy UAS in the National Airspace System continues to drive the national discussion. Radio spectrum, communications infrastructure, and strategies for aircraft separation were presented as areas of greatest need by a panel of industry, university, and FAA experts assembled at the Infotech@Aerospace 2011 conference in St. Louis. Budget disputes in Congress led to a partial shutdown of the FAA from July 23 to August 5. While one of the side effects was the (short-lived) reduction of commercial airfares, another was stalled COAs (certificates of authorization) for a number of UAS applicants.

*On April 27 Boeing announced the first flight of the Phantom Ray.*

Converting off-the-shelf hobbyist kits into small UAS is a common practice, particularly in university programs, and offers low-cost airframes for small-UAS applications. The fear of attack by a terrorist using a remote-controlled high-performance hobbyist aircraft has been of concern for several years. The September arrest of a terrorism suspect who allegedly planned to use converted hobbyist aircraft to bomb federal buildings in the Washington, D.C., area reinforced this concern, although there is some debate on the potential effectiveness of this technique. The use of small UAS by law enforcement agencies continues to expand, with COAs being issued this year to include more widespread flights in urban areas such as those in Arlington, Texas, and Mesa County, Colorado.

Meanwhile, at home and abroad, U.S. military UAS continued to make headlines. Boeing announced the first flight of the Phantom Ray at Edwards AFB on April 27. The vehicle continues the Boeing X-45 legacy and might position the company to compete with the Northrop Grumman X-47 unmanned combat air system, and with derivatives of General Atomics' Predator C/Avenger that first flew in April 2009.

In another first, on April 25, the Army flew the General Atomics Grey Eagle UAS in night flights with the first COA for sense-and-avoid flights. On 1 May, President Obama announced the death of Osama Bin Laden in an operation that has been reportedly supported by the Lockheed Martin RQ-170 Sentinel UAS, the 'Beast of Kandahar.' This was followed in September with the announcement of the killing of Anwar al-Awlaki, an American jihadist operating from Yemen, in an airstrike delivered by armed UAS and manned aircraft. While the moral and ethical issues surrounding robotic warfare have been a topic of discourse and debate for years, the growing number of UAS deployed by the U.S. military and the growing list of successes are only adding to the discussion.

In collaboration with the National Oceanic and Atmospheric Administration (NOAA), NASA continued development and deployment of its Global Hawk UAS. The Global Hawk team flew practice runs over the Gulf of Mexico and Atlantic Ocean for the upcoming NASA Hurricane and Severe Storm Sentinel mission, in addition to supporting the NOAA-led Winter Storms and Pacific Atmospheric Rivers field campaign to demonstrate a new NCAR dropsonde system, and to improve understanding of how 'atmospheric rivers' transport large quantities of water vapor over the western U.S.

NASA has also partnered with DARPA on the KQ-X project to demonstrate in-air refueling using Global Hawks, and modifications to the aircraft have begun. In June, the NASA SIERRA flew a carbon/methane/water vapor flux payload in support of the JAXA GOSAT and NASA OCO2 mission teams. UAS activities at NASA Goddard's Wallops Flight Facility included tests of the L-3 Viking 300 with a variety of advanced instrumentation and data systems. This work is in support of development of a miniaturized topographic lidar system. A primary goal is to create a system suitable for cryospheric research, which will also result in a capability that will be useful for a variety of other applications, including coastal erosion monitoring.

by **Brian Argrow** and the **AIAA Unmanned Systems Program Committee**

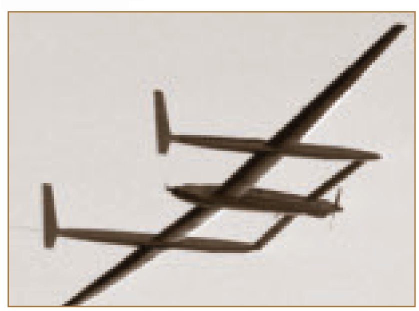
# Out of the

## 25 Years Ago, December 1986

**Dec. 2** An Air France Concorde supersonic airliner completes a round-the-world flight carrying 94 passengers. The trip takes 18 days in easy stages; the actual flight time is only 31 hr and 51 min. B. Gunston (ed.), *Aviation Year-by-Year*, p. 812.

**Dec. 11** The first McDonnell Douglas F-15E Strike Eagle all-weather, long-range deep interdiction attack aircraft completes its first flight, from Lambert Field, St. Louis. The F-15E is a two-seat version of the F-15 fighter equipped with instruments optimized for all weather and night conditions while maintaining its impressive air-to-air capabilities. *Jane's All the World's Aircraft, 1987-88*, p. 457.

**Dec. 14-23** The first nonstop flight around the world is made by Jeana Yeager and Dick Rutan in the Voyager aircraft, powered by two engines, a Teledyne Continental Type 0-240 of 130 hp in the front and a 110-hp IOL-200 in the rear. Designed and built by the Rutan Aircraft Factory in Mojave, Calif., Voyager has a wingspan of 110 ft 10 in., a length of 25 ft 5 in., and a height of 10 ft 4 in. The 25,012-mi. journey takes 9 days 3 min 44 sec and begins and ends at Edwards AFB, Calif. The average speed is 115 mph with the gas coming from 17 fuel tanks. *New York Times*, Dec. 24, 1986; *Newsweek*, Jan. 5, 1987, p. 28.



**Dec. 31** The Israeli IAI Lavi multirole fighter flies for the first time. The all-composite single-engine aircraft features a delta main wing and large canards behind the cockpit. Designed for high maneuverability in air-to-air combat, precision bombardment, and high survivability, it is expected to replace the Skyhawks and Kfirs currently in service. *Jane's All the World's Aircraft, 1987-88*, p. 457.

## 50 Years Ago, December 1961

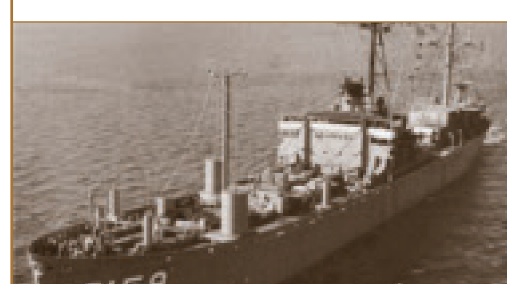
**Dec. 1** The Navy's Sikorsky HSS-2 twin-turbine helicopters set three world records for speed: 182.8 mph for 100 km, 179.5 mph for 500 km, and 175.3 mph for 1,000 km. *The 1962 Aerospace Year Book*, p. 471.

**Dec. 4** The Sacred Cow, an Air Force C-54 that had earlier been the personal transport plane of Presidents Roosevelt and Truman as well as many other VIPs, is donated to the National Air Museum (later called the National Air and Space Museum) of the Smithsonian Institution. First delivered to the USAF's Air Transport Command in June 1944, the plane was officially retired in July 1961. *The Aeroplane*, Dec. 21, 1961, p. 797.

**Dec. 9** A huge (43-ft-long, 96-in.-diam.) 70-ton segmented solid-propellant rocket motor of 425,000-lb thrust is successfully test fired before Air Force officials by its developer, United Technology, at the firm's Development Center near Morgan Hill, Calif. The test is a demonstration of the company's development capability in the upcoming Air Force competition for a 120-in.-diam. rocket motor planned for use in a variety of space booster applications. *Aviation Week*, Dec. 18, 1961, pp. 30-31.

**Dec. 13** DOD announces that it has abandoned the plan for a mobile Minuteman ICBM. The concept called for 600 to be placed into service—450 in silos and 150 on special trains, each train carrying five missiles. *Flight*, Dec. 21, 1961, p. 944.

**Dec. 17** While at sea between New York and Norfolk, Va., the USS Oxford communications research ship receives two radio messages bounced off the Moon, using the ship's 16-ft antenna. The messages had been transmitted from a 60-ft antenna at Stump Neck, Md. This is the first time a ship receives messages via the Moon. *The Aeroplane*, Dec. 28, 1961, p. 804.




**Dec. 20** X-15 No. 3 makes its first flight, with NASA test pilot Neil A. Armstrong at the controls. Armstrong later becomes an astronaut for projects Gemini and Apollo and on July 21, 1969, is the first man to set foot on the Moon. The flight of X-15 No. 3 is primarily to check out the aircraft, which reaches a speed of 2,502 mph and a maximum altitude of 81,000 ft. *Aviation Week,* Dec. 25,

# Past

An Aerospace Chronology
by **Frank H. Winter**
and **Robert van der Linden**

1961, p. 23; D. Jenkins, *X-15: Extending the Frontiers of Flight*, p. 620.

**Dec. 21** The Nike-Zeus antimissile missile makes its first live interception of another missile in a test at White Sands Proving Ground, N.M. The target missile is a Nike-Hercules traveling at about 3,000 mph as it plunges into the lower atmosphere, like a reentry vehicle, after having climbed to about 150,000 ft. *Flight*, Jan. 4, 1962, p. 6.

**Dec. 28** A series of test firings of the Pershing tactical missile from a mobile erector is successfully completed. Heat and blast measurements are part of the testing. *Aviation Week*, Jan. 8, 1962, p. 33.

## And During December 1961

—Navy Cdr. Alan B. Shepard and Air Force Capt. Virgil I. Grissom are presented the new award of Astronaut Wings by the Dept. of Defense for their recent suborbital Project Mercury flights. *Aviation Week,* Jan. 1, 1962, p. 59.

—The Russians send an An-12 and an Il-19 aircraft from Moscow to the Russian south polar base at Mirny in Antarctica, to establish a direct air service there from Moscow. *Aviation Week*, Jan. 1, 1962, p. 4; *The Aeroplane*, Jan. 4, 1962, p. 4.

## 75 Years Ago, December 1936

**Dec. 7** Noted French test pilot Jean Mermoz of Air France is lost over the South Atlantic when he and his aircraft, the Latecoere 300 Croix du Sud, go down somewhere between Dakar, Senegal, and Brazil. B. Gunston (ed.), *Aviation Year-by-Year*, p. 332.

**Dec. 14** Maj. Alexander P. de Seversky, air power advocate and head of Seversky Aircraft, sets a new speed record for flying between New York and Miami when he pilots his Seversky SEV 3, arriving at his destination from Floyd Bennett Field, N.Y., in 5 hr 46 min 30 sec. *Aircraft Year Book, 1937*, p. 414.

**Dec. 19** Five days after setting the speed record between New York and Miami, Maj. Alexander P. de Seversky sets a world speed record for amphibian aircraft for 100 km, flying at 209.40 mph. Once again he pilots his SEV 3. *Aircraft Year Book, 1937*, p. 414.

**Dec. 21** From the factory airfield at Dessau, Germany, the prototype Junkers Ju 88V-1 completes its maiden flight. The twin-engine, high-speed medium bomber becomes one of the Luftwaffe's most successful and versatile aircraft during WW II. J. Smith and A. Kay, *German Aircraft of the Second World War*, pp 394-395.


ANT-42

**Dec. 27** Flown by famed Soviet test pilot Mikhail Gromov, the Tupolev ANT-42 completes its first flight. Designated the TB-7, this modern all-metal four-engine bomber is the Soviet Union's attempt to produce a long-range strategic bomber. It was designed by Andrei Tupolev before his arrest and imprisonment by the Soviet secret police. Because of changing military priorities, few were made, especially after the outbreak of the war with Germany, when fighters and tactical bombers had a much higher priority. Y. Gordon and V. Rigmant, *OKB Tupolev: A History of the Design Bureau and its Aircraft*, pp. 74-76.

**Dec. 30** In a Renault-powered Caudron Simoun aircraft, Maryse Bastie flies solo in a record time of 12 hr 5 min between Dakar, Senegal, and Natal, Brazil. *Aircraft Year Book 1937*, p. 414.

## 100 Years Ago, December 1911

**Dec. 27** Test pilot and future aircraft designer Geoffrey de Havilland takes the first Royal Aircraft Factory B.E.1 on its maiden flight, from the airfield at Farnborough, England. B. Gunston (ed.), *Aviation Year-by-Year*, p. 86.

## Subjects

### AIRCRAFT DESIGN AND TECHNOLOGY



### AVIONICS AND ELECTRONICS



### COMMUNICATIONS



### COMPUTERS AND SOFTWARE



### ECONOMICS



### ENVIRONMENT



### INSTRUMENTATION AND TECHNOLOGY



### INTERNATIONAL

## LIFE SCIENCES



## MANAGEMENT



## MATERIALS AND STRUCTURES



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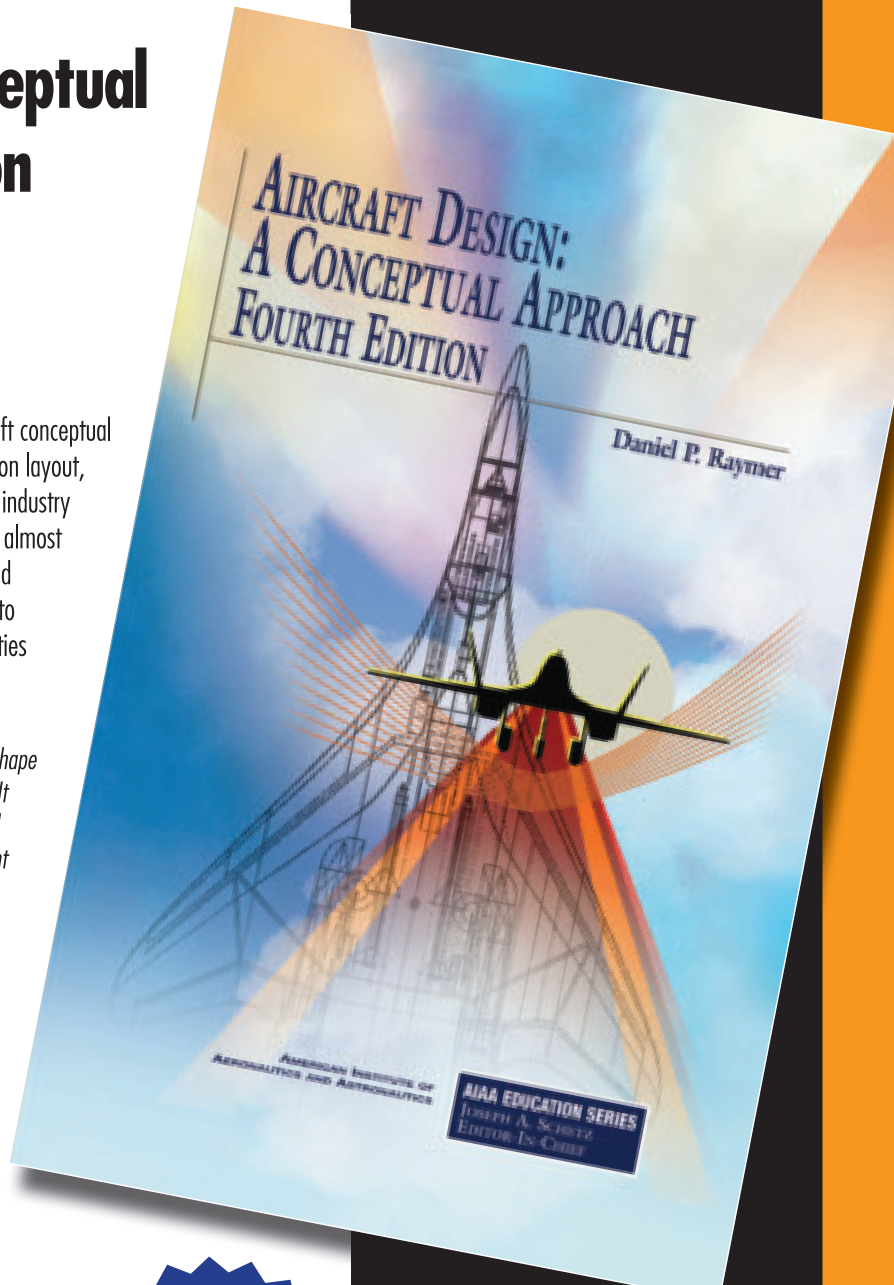


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**McGill University**
**Department of Mechanical Engineering**
**Tenure-Track Faculty positions**

The Department of Mechanical Engineering at McGill University invites applications for two faculty positions. The first position is in the area of Design and Manufacturing, with a focus on computer-aided design or mechatronics. It is expected to be filled at the Assistant Professor level, although exceptional applications will be considered at all ranks. The second position is in the area of Aeronautics, with a focus on aerodynamics or aeroelasticity. It is for senior faculty with a proven track record who will be considered for a Tier 1 Canada Research Chair position, and will be recommended for appointment at the tenured Full Professor level.

Candidates must have a Ph.D. and a strong commitment to excellence in research and teaching. Evidence of outstanding research achievements, or research potential, is indispensable. Membership or eligibility for membership in a Canadian professional engineering association is required.

Applications will be reviewed as they are received. To be considered, applications must be received by January 31, 2012. The positions are expected to be filled by August 31, 2012.

Qualified applicants are required to submit a resume, together with names and contact information (mail, phone, and email) of three references, and a two-page statement outlining research and teaching goals to:

Luc Mongeau
Chair, Departmental Search Committee
Macdonald Engineering Building, Room 270
817 Sherbrooke Street West
Montreal, Quebec, H3A 2K6 Canada
E-mail (preferred): Facultysearch.mecheng@mcgill.ca

McGill University is committed to equity in employment and diversity. It welcomes applications from indigenous peoples, visible minorities, ethnic minorities, persons with disabilities, women, persons of minority sexual orientations and gender identities, and others who may contribute to further diversification.

All qualified applicants are encouraged to apply; however, Canadians and permanent residents will be given priority.

# CLARKSON UNIVERSITY

## Wallace H. Coulter School of Engineering
## Department of Mechanical and Aeronautical Engineering
## Two Tenure Track Faculty Positions

**Mechanical and Aeronautical Engineering (MAE) Department** of the Wallace H. Coulter School of Engineering (CSoE) at Clarkson University invites applications for two tenure track positions at the Assistant Professor rank (anticipated starting date: August 20 12). **A Ph.D. or in the process of completing a Ph.D. in Mechanical Engineering, Aeronautical/Aerospace Engineering or related field is required.** Applications are encouraged from individuals whose research programs can contribute to areas of: (1) Solid Mechanics/Materials, (2) Thermal Sciences, (3) Bioengineering and/or (4) Renewable/Sustainable Energy Systems including Solar and Nuclear Energy, which are within the interdisciplinary focus areas of the department/school/university.

Clarkson's MAE Department offers B.S. degrees in Mechanical Engineering and Aeronautical Engineering, and M.E., M.S. and Ph.D. degrees in Mechanical Engineering. S**uccessful candidates will be expected to teach fundamental undergraduate and graduate courses in mechanical/aeronautical engineering, and develop strong funded research programs.** Applicants need to articulate a clear and substantiated vision of how their background can lead to sustained accomplishments through teaching, research, and an ability to engage in interdisciplinary activities and projects within one of the focus areas identified above. Clarkson University is committed to providing an educational experience in which students develop an appreciation for diversity in both working and living environments.

To submit your application, go to www.clarkson.edu/hr and click **"Career Opportunities"** on the left hand navigation bar. Review of applications will begin immediately and will continue until the position is filled.

Additional information about the MAE Department and the Coulter School of Engineering can be found at www.clarkson.edu. Clarkson University has one of the highest percentages of women engineering faculty in the nation (ASEE 2005 profiles of Engineering Colleges).

***An equal opportunity/affirmative action employer, Clarkson University actively seeks and encourages applications from minorities, women, people wzth disabilities and veterans.***

Please reference Job Posting# Fac 2009000223

**College of Engineering and Applied Sciences**
**Department of Mechanical & Aeronautical Engineering**

## Position Description

**Position**

A tenure-track position at the assistant or associate professor level in the Department of Mechanical and Aeronautical Engineering starting Fall 2012. Rank and salary depend upon qualifications and experience.

**Responsibilities**

The successful candidate is expected to teach undergraduate and graduate courses in mechanical and aeronautical engineering, advise graduate and undergraduate students, conduct research relevant to aerospace engineering, supervise master's and Ph.D. theses, and serve on university, college, and department committees. The candidate also is expected to develop new courses, as necessary, and the associated laboratory facilities.

**Academic and Professional Qualifications**

Candidates must hold an earned doctoral degree in aerospace engineering or related discipline. Applicants with a strong background in space propulsion and other space related disciplines will be considered. Preference will be given to candidates with proven research and publication record and with potential to achieve externally funded research.

**The Department**

The Department of Mechanical and Aeronautical Engineering currently enrolls about 50 students in the M.S. and Ph.D. programs, and 580 undergraduate students. The department is in the process of changing the aeronautical engineering program to aerospace engineering. This position is because of this change and recent enrollment growth in aeronautical engineering. The aeronautical engineering program is accredited by EAC/ABET.

**The University and Community**

Western Michigan University is a Carnegie doctoral research extensive institution serving more than 25,000 students at its main and branch campuses. The Carnegie Foundation for the Advancement of Teaching has placed WMU among the 76 public institutions in the nation designated as a research university with high research activity. Kalamazoo is in a metropolitan area in southwestern Michigan, midway between Chicago and Detroit, with a population of 200,000. The College of Engineering and Applied Sciences offers 18 bachelor's degree programs, 11 master's programs, and 6 doctoral programs. A 270-acre engineering campus opened in summer 2003 includes a new building for the College of Engineering and Applied Sciences as well as a Business Technology and Research Park.

For position description details and application procedures, visit our website: http://www.wmich.edu/hr/careers-at-wmu.html. Applications must include: a cover letter highlighting your qualifications; curriculum vitae; statement of teaching and research interests; along with names and affiliation of three references. Western Michigan University is an EO employer.

Review of applications will begin on **January 15, 2012** and continue until the position is filled

*Western Michigan University is an affirmative action/equal opportunity employer consistent with applicable federal and state law. All qualified applicants are encouraged to apply.*

Located in the heart of Toronto, the largest and most culturally diverse city in the country, Ryerson University is committed to diversity, equity and inclusion. The University is known for innovative programs built on the integration of theoretical and practically oriented learning. Our undergraduate and graduate programs are distinguished by a professionally focused curriculum and strong emphasis on excellence in teaching, research and creative activities. Ryerson is also a leader in adult learning, with the largest university-based continuing education school in Canada.

# TENURE-TRACK FACULTY POSITION

## DEPARTMENT OF AEROSPACE ENGINEERING

The Department of Aerospace Engineering at Ryerson University has a complement of 16 faculty members and offers a four-year accredited program leading to a Bachelor of Engineering degree in Aerospace Engineering. In addition, the Department offers a graduate program leading to either an M.A.Sc. or M.Eng. and PhD degrees in Aerospace Engineering. The Department invites applications for a tenure-track faculty position in areas related to avionics and space systems, at the Assistant/Associate Professor level, commencing August 1, 2012, subject to budgetary approval. The successful candidate will need to have teaching and research expertise in areas related to avionics and space systems.

The primary qualifications for the position, in addition to an earned doctorate in Aerospace Engineering or a closely related discipline, are demonstrated ability to perform high-quality research, an established record of, or potential for, outstanding teaching and supervising of students at undergraduate and graduate levels, and participating in departmental academic affairs, and ability to establish viable externally funded research programs. Specifically, applicants must have demonstrated outstanding research and an aptitude in teaching in areas including, but not limited to, avionics and space systems design and analysis. Both analytical and experimental research is of strong interest. Applicants should be registered or eligible for registration as a professional engineer in Ontario.

Ryerson's Department of Aerospace Engineering is one of the fastest growing programs of its kind in Canada. Committed to offering the best environment for academic growth, the Department has grown to become a powerhouse of innovative research and teaching. With 450 outstanding undergraduate and graduate students, the Department of Aerospace Engineering plays a key role in preparing the next generation of Aerospace Engineers while promoting education and research across Canada. The Department maintains strong relationships with Canada's top aerospace companies, and has tripled its industrial research funding since 2009. It is committed to developing further research collaborations built on the three main pillars: universities, government and industry.

Applications, with a curriculum vitae, a research statement outlining current and future research interests and a specific research plan, a teaching statement, selected reprints of not more than three publications, and the names and addresses of three referees, should be sent to: Dr. Paul Walsh, Interim Chair, Department of Aerospace Engineering, Ryerson University, 350 Victoria Street, Toronto, Ontario, Canada, M5B 2K3. Fax: 416-979-5056. E-mail: paul.walsh@ryerson.ca. Review of applications will begin January 1, 2012 and will continue until a suitable candidate is found. We thank all candidates for applying; however, only those selected for an interview will be contacted.

This position falls under the Ryerson Faculty Association, (www.ryerson.ca/~rfa) jurisdiction. For details on the Ryerson Faculty Association Collective Agreement and the University's RFA Benefits Summary, please visit: www.ryerson.ca/teaching/employmentresources/rfa.html and www.ryerson.ca/hr/working/etoolkit/benefits/rfa

Ryerson University is strongly committed to fostering diversity within our community. We welcome those who would contribute to the further diversification of our staff, our faculty and its scholarship including, but not limited to, women, visible minorities, Aboriginal people, persons with disabilities and persons of any sexual orientation or gender identity. All qualified candidates are encouraged to apply, but applications from Canadians and permanent residents will be given priority.

RYERSON UNIVERSITY

**www.ryerson.ca** Everyone Makes a Mark

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WPI

**Worcester Polytechnic Institute**

### Multiple Faculty Positions in Mechanical, Materials Science, and Aerospace Engineering

The Mechanical Engineering Department at the Worcester Polytechnic Institute invites applications for multiple faculty positions in Mechanical, Materials Science, and Aerospace Engineering at the Assistant, Associate, and Full Professor levels. Candidates are expected to develop and maintain active research, teaching, and project activities that complement and expand the programs within the department or in related interdisciplinary areas such as robotics and automation, MEMS and nano-scale applications, energy systems, advanced computational modeling, biomedical systems, and materials processing. These searches will remain open until the positions are filled.

Mechanical Engineering Design: Primary areas of interest include computer-aided design, machine design, kinematics, design optimization, or computer-aided engineering. Candidates with experience in the practice of engineering design are encouraged to apply.

Aerospace Engineering: Primary areas of interest include: (1) aircraft and/or spacecraft dynamics and controls; flight mechanics; guidance, navigation and communication; autonomous aerospace systems. (2) aircraft and/or spacecraft structures; aerospace structural dynamics; adaptive aerospace structures or other closely related areas.

Materials Science and Engineering: Areas of interest span all classes of materials and include materials processing, performance and reliability, nanostructured materials, computational materials engineering, and materials for energy systems and environmental sustainability.

WPI, founded in 1865 and located one hour west of Boston, is one of the nation's oldest technological universities. WPI is a highly selective private university with an undergraduate student body of over 3,600 and 1,400 full-time and part-time graduate students enrolled in more than 50 Bachelor's, Master's, and Ph.D programs. Its innovative project-enriched curriculum engages students and faculty in real-world problem solving, often at one of WPI's global project centers. U.S. News and World Report consistently ranks WPI among the top national universities. Recently Unigo's "Colleges for 21st Century Einsteins," listed WPI among the top 10 schools for science and technology as rated by students.

**Requirements:**
Candidates are expected to develop and maintain active research, teaching, and project activities that complement and expand the programs within the department or in related interdisciplinary areas such as robotics and automation, MEMS and nano-scale applications, energy systems, advanced computational modeling, biomedical systems, and materials processing. These searches will remain open until the positions are filled.

Applications should be sent to me-recruit@wpi.edu

Applications should include a curriculum vitae, statement of teaching and research interests, and a list of five professional references.

To enrich education through diversity,
WPI is an affirmative action, equal opportunity employer.
--A member of the Colleges of Worcester Consortium--

## College of Engineering

Department: Mechanical and Aerospace Engineering
Position Title: Academic Department Head, Tenure Track Req # 011003657
Rank: Professor
Date Position Advertised: October 6, 2011
Salary: Commensurate with education and experience

Special Conditions: We seek a nationally and internationally recognized educator and researcher. The candidate will become the holder of the Bob and Sherry Myers Chair in Mechanical and Aerospace Engineering. The department has strong research programs in Aeroelasticity and Fluid Structure Interaction, Dynamics and Vibrations, Fluid Mechanics, Robotics and Controls, Solid Mechanics and Materials, and, Thermal Science and Energy. The MAE Department offers an ABET Inc. accredited B.S. degree program, as well as M.S. and Ph.D. programs in both mechanical and aerospace engineering. Detailed departmental information is available at http://me.nmsu.edu . The department currently has 14 FTE faculty positions, over 500 undergraduate students, and over 50 graduate students. The department currently has 1 endowed professorship.

Qualifications: Candidates must have an earned doctoral degree in Mechanical or Aerospace Engineering or closely related field. The applicant must show a sustained record of scholarly activities and research as evidenced by archival publications, graduate supervision, and nationally competitive funding. Qualifications include a strong record of scholarly and professional accomplishments that merit appointment as a tenured full professor, a reputation for creating a positive people climate, a record of management in a complex organization, a demonstrated commitment to diversity and student success, and excellent interpersonal skills.

Examples of Duties: Academic, administrative, budgetary and personnel decisions, sustaining the ABET accreditation, recruiting and retention of students and faculty, providing innovative and energetic leadership in teaching, research, extension, outreach, development activities and securing research sponsorship. The successful candidate must articulate and communicate a clear vision to lead the MAE Department towards academic excellence and must have excellent communication skills to proactively interface with a broad constituency in academia, government, industry and the community; a demonstrated record of organizational skills; knowledge of state, federal and private sector fund-raising; and the ability to develop R&D relationships.

Benefits Offered: Group medical and hospital insurance, group life insurance, long-term disability insurance, state educational retirement, workers' compensation, sick leave, annual leave and unemployment compensation. Opportunities for educational advancement are available.

Reply to/Deadline for Applications: Submit a detailed curriculum vita with a description of management philosophy and administration experience, a statement of vision for the department and a statement of research and teaching interests. Include a list of four references with contact information including name, address, telephone, and email.

Submit all material by electronic submission in one PDF file. Email the materials to maedhsch@nmsu.edu with the words " MAE Department Head Search" in the subject line.

Reply to:
Dr. Edward Pines, Search Committee Chair
College of Engineering, MSC 4230
New Mexico State University
P.O. Box 30001
Las Cruces, NM 88003
Telephone- (575) 646-4923
Fax- (575) 646-2976

Screening of applications will begin January 17, 2012. Applications received after this date may be considered.

NMSU is an equal opportunity/affirmative action employer. Women and minorities are strongly encouraged to apply. All offers of employment, oral and written, are contingent on the university's verification of credentials, individual's eligibility for employment in the United States and other information required by federal law, state law, and NMSU policies/procedures, and may include the completion of a criminal history check .

## The Robert A. Heinlein Endowed Chair in Aerospace Engineering

The U.S. Naval Academy announces its search for a distinguished professor in the field of astronautics to fill the Robert A. Heinlein Chair in Aerospace Engineering. Created in honor of the award winning novelist and alumnus Robert A. Heinlein (USNA '29), the Heinlein Chair has made outstanding contributions to teaching and research in the astronautics curriculum.

The Naval Academy is a leader in university small satellite and space experiment development having participated in six spaceflight experiments since 2001 in collaboration with other NASA or DoD entities including several NASA centers, Naval Research Laboratory and DoD Space Test Program (STP). The astronautics curriculum resides in the Aerospace Engineering Department alongside an equally distinguished aeronautics curriculum. Future Navy, Marine and civic leaders pass through each of our classrooms. Graduates have included leaders of the Naval Air Systems Command, aircraft and spacecraft development programs in DoD and NASA, innovative business leaders and more astronauts than any other single institution.

The successful applicant must have significant experience as a technical leader in the field of astronautics including spacecraft development during all phases from concept exploration to launch. Concentrations of interest are spacecraft bus subsystem and payload development, integration and test including launch integration, space transportation and related disciplines including space environment effects. Specific responsibilities include classroom instruction and scholarly research, which should include midshipmen research. The ability to effectively teach a significant portion of the astronautics curriculum including capstone design is important.

The applicant should have an earned Doctorate, but candidates with strong industrial/laboratory experience will be considered. The applicant must be able to function effectively in a university environment including a demonstrated capacity to conduct scholarly research, a strong commitment to undergraduate engineering education, and excellent communications skills. State of the art research is anticipated and the Heinlein Chair may seek outside research funding within Navy regulations and Naval Academy practice.

Please send a letter of intent, a statement of your vision for the Heinlein Chair and description of research/scholarly interests, resume/curriculum vitae, transcripts and the names of three professional references (include complete contact information for your references) to:

Heinlein Chair Search Committee
Attention: Commander David D. Myre
Aerospace Engineering Department (MS-11B),
U.S. Naval Academy, Annapolis MD 21402
dmyre@usna.edu
Ph: 410-293-6411, Fax: 410-293-6404

**Candidates are encouraged to submit promptly. Review of applications will commence 1 February 2012 and will continue until the position is filled. Preference will be given to U.S. citizens.**
*The U.S. Naval Academy is an Affirmative Action/Equal Opportunity Employer*

## SAN JOSÉ STATE UNIVERSITY

### ASSISTANT PROFESSOR, AEROSPACE ENGINEERING
### DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING

Applications are invited from applicants who have a doctorate in Aerospace Engineering or closely related field, and specialization either in flight vehicle dynamics/controls or structures/ materials with multidisciplinary, emerging technology applications. Responsibilities include teaching undergraduate and graduate courses in the applicant's specialization, and providing leadership in the specialization for laboratory development and supervision of senior and graduate design projects. General responsibilities include advising of graduate and undergraduate students, community and professional service, and scholarship. MAE Department faculty collaborate in instruction, student and industry projects, and research with each other and with other faculty within and outside the College. The successful candidate will be expected to develop multidisciplinary applications with college faculty and industry partners. The Department has MS and ABET-accredited BS degree programs in both disciplines, and combined enrollments of about 785 undergraduate (181 AE) and about 148 graduate (38 AE) students. Our programs are strongly lecture-lab oriented, are well-known for providing excellent hands-on engineering education, and have faculty and students involved in a variety of projects, many with industry collaboration. The College is the leading provider of entry-level engineers to Silicon Valley industry. Salary range is commensurate with qualifications and experience. Starting date is August 20, 2012. Employment is contingent upon proof of eligibility to work in the United States. For full job announcement including qualifications and responsibilities, please visit our website at http://apptrkr.com/213271 (JOID 14184). For full consideration, please send a letter of application, complete curriculum vitae, statement of teaching and research interests, experience and plans to the Search Committee, and arrange for at least three original letters of reference with contact information to be sent directly to the Committee by February 1, 2012 to: Chair, AE Search Committee, Mechanical and Aerospace Engineering Dept, San José State University, One Washington Square, San José, CA 95192-0087. San Jose State University is an Equal Opportunity/Affirmative action employer committed to the core values of inclusion, civility, and respect for each individual.

SAN JOSÉ STATE
UNIVERSITY

## STANFORD UNIVERSITY
## DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

The Department of Aeronautics and Astronautics at Stanford University invites applications for a tenure-track faculty position at the Assistant or untenured Associate Professor level. Research advances in the fundamental areas of aerospace engineering are critical to meeting increases in demand for air transportation, improving technologies for increased autonomy, and achieving breakthroughs in space flight and satellite design, while ensuring safety and security, and protecting the environment. We are seeking exceptional applicants who will develop a program of research and innovative new courses at the frontier of areas such as space systems engineering, cyber-physical systems, autonomous systems, control and navigation, aviation and the environment, system simulation and design, and aerospace structures and materials. This is a broad-area search. We will place higher priority on the impact, originality, and promise of the candidate's work than on the particular sub-area of specialization within Aeronautics and Astronautics. Evidence of the ability to pursue a program of innovative research and a strong commitment to graduate and undergraduate teaching are required. The successful candidate will be expected to teach courses at the graduate and undergraduate levels and to build and lead a team of graduate students in Ph.D. research. Applicants whose research programs in Aeronautics and Astronautics will involve the development of sophisticated computational and/or mathematical methods may be considered for a joint appointment in the Institute for Computational and Mathematical Engineering (http://icme.stanford.edu).

Applicants should include a cover letter, their curriculum vitae, a list of publications, a one-page statement of research vision, a one-page statement of teaching interests, and the names of five potential references. Please submit these materials as a single PDF file labeled "AA_Search_LastName_FirstName.pdf" to aasearch@lists.stanford.edu. For additional information, please contact Professor Juan J. Alonso (jjalonso@stanford.edu).

Applications will be accepted until the position is filled; however the review of applications will begin on January 3, 2012.

*Stanford University is an equal opportunity employer and is committed to increasing the diversity of its faculty. It welcomes nominations of and applications from women and members of minority groups, as well as others who would bring additional dimensions to the university's research and teaching missions.*

# AIAA Bulletin

At the Baikonur Cosmodrome in Kazakhstan on 14 November, the Soyuz TMA-22 rocket is seen at the Soyuz launch pad during a snowstorm before the successful launch of Expedition 29 to the International Space Station. Expedition 29 crew members are Anton Shkaplerov, Anatoly Ivanishin, and Dan Burbank (*photo credit: NASA/Carla Cioffi*). Video of the launch can be found at http://www.nasa.gov/multimedia/video-gallery/index.html?collection_id=14555&media_id=120498101.

## DECEMBER 2011



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* Also accessible via Internet. Use the formula first name last initial@aiaa.org. Example: megans@aiaa.org.
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Addresses for Technical Committees and Section Chairs can be found on the AIAA Web site at **http://www.aiaa.org**.

We are frequently asked how to submit articles about section events, member awards, and other special interest items in the *AIAA Bulletin*. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the *AIAA Bulletin* Editor.

# **Meeting** Schedule

| DATE | MEETING (Issue of *AIAA Bulletin* in which program appears) | LOCATION | CALL FOR PAPERS (*Bulletin* in which Call for Papers appears) | ABSTRACT DEADLINE |
|---|---|---|---|---|
| **2012** | | | | |
| 9–12 Jan | **50th AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition** | Nashville, TN | *Jan 11* | **1 Jun 11** |
| 23–26 Jan† | **The Annual Reliability and Maintainability Symposium (RAMS)** | Reno, NV (Contact: Patrick M. Dallosta, patrick.dallosta@dau.mil; www.rams.org) | | |
| 24–26 Jan | **AIAA Strategic and Tactical Missile Systems Conference**<br>**AIAA Missile Sciences Conference** (Oct)<br>**(SECRET/U.S. ONLY)** | Monterey, CA | *Jun 11* | **30 Jun 11** |
| 29 Jan–2 Feb† | **22nd AAS/AIAA Space Flight Mechanics Meeting** | Charleston, SC<br>Contact: Keith Jenkins, 480.390.6179; keith@jenkinspatentlaw.com; www.space-flight.org | *Apr 11* | **3 Oct 11** |
| 15–16 Feb | **15th Annual FAA Commercial Space Transportation Conference** | Washington, DC | | |
| 3–10 Mar† | **2012 IEEE Aerospace Conference**, | Big Sky, Montana<br>Contact: David Woerner, 626.497.8451; dwoerner@ieee.org; www.aeroconf.org | | |
| 21–23 Mar† | **Nuclear and Emerging Technologies for Space 2012 (NETS-2012) held in conjunction with the 2012 Lunar & Planetary Sciences Conference** | The Woodlands, TX<br>Contact: Shannon Bragg-Sitton, 208.526.2367, shannon.bragg-sitton@inl.gov, http://anstd.ans.org/NETS2012.html | | |
| 26–28 Mar† | **3AF 47th International Symposium of Applied Aerodynamics** | Paris, France (Contact: Anne Venables, 33 1 56 64 12 30, secr.exec@aaaf.asso.fr, www.aaaf.asso.fr) | | |
| 23–26 Apr | **53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference**<br>**20th AIAA/ASME/AHS Adaptive Structures Conference**<br>**14th AIAA Non-Deterministic Approaches Conference**<br>**13th AIAA Gossamer Systems Forum**<br>**8th AIAA Multidisciplinary Design Optimization Specialist Conference** | Honolulu, HI | *Apr 11* | **10 Aug 11** |
| 14–18 May† | **12th Spacecraft Charging Technology Conference** | Kitakyushu, Japan<br>Contact: Mengu Cho, +81 93 884 3228, cho@ele.kyutech.ac.jp, http://laseine.ele.kyutech.ac.jp/12thsctc.html | | |
| 22–24 May | **Global Space Exploration Conference (GLEX)** | Washington, DC | *Oct 11* | **1 Dec 11** |
| 4–6 Jun | **18th AIAA/CEAS Aeroacoustics Conference (33rd AIAA Aeroacoustics Conference)** | Colorado Springs, CO | *Jun 11* | **9 Nov 11** |
| 4–6 Jun† | **19th St Petersburg International Conference on Integrated Navigation Systems** | St. Petersburg, Russia<br>Contact: Prof. V. Peshekhonov, +7 812 238 8210, elprib@online.ru, www.elektropribor.spb.ru | | |
| 18–20 Jun† | **3rd International Air Transport and Operations Symposium (ATOS) and 6th International Meeting for Aviation Product Support Process (IMAPP)** | Delft, the Netherlands<br>Contact: Adel Ghobbar, 31 15 27 85346, a.a.ghobbar@tudelft.nl, www.lr.tudelft.nl/atos | | |
| 19–21 Jun | **AIAA Infotech@Aerospace Conference** | Garden Grove, CA | *Jun 11* | **6 Dec 11** |
| 25–28 Jun | **28th Aerodynamics Measurement Technology, Ground Testing, and Flight Testing Conferences including the Aerospace T&E Days Forum**<br>**30th AIAA Applied Aerodynamics Conference**<br>**4th AIAA Atmospheric Space Environments Conference**<br>**6th AIAA Flow Control Conference**<br>**42nd AIAA Fluid Dynamics Conference and Exhibit**<br>**43rd AIAA Plasmadynamics and Lasers Conference**<br>**44th AIAA Thermophysics Conference** | New Orleans, LA | *Jun 11* | **17 Nov 11** |
| 27–29 Jun† | **American Control Conference** | Montreal, Quebec, Canada<br>Contact: Tariq Samad, 763.954.6349, tariq.samad@honeywell.com, http://a2c2.ort/conferences/acc2012 | | |
| 11–14 Jul† | **ICNPAA 2012 – Mathematical Problems in Engineering, Aerospace and Sciences** | Vienna, Austria<br>Contact: Prof. Seenith Sivasundaram, 386/761-9829, seenithi@aol.com, www.icnpaa.com | | |

| DATE | MEETING (Issue of *AIAA Bulletin* in which program appears) | LOCATION | CALL FOR PAPERS (*Bulletin* in which Call for Papers appears) | ABSTRACT DEADLINE |
|---|---|---|---|---|
| 14–22 Jul | **39th Scientific Assembly of the Committee on Space Research and Associated Events (COSPAR 2012)** | Mysore, India<br>Contact: http://www.cospar-assembly.org | | |
| 15–19 Jul | **42nd International Conference on Environmental Systems (ICES)** | San Diego, CA | *Jul/Aug 11* | **15 Nov 11** |
| 30 Jul–1 Aug | **48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit Future Propulsion: Innovative, Affordable, Sustainable** | Atlanta, GA | *Jul/Aug 11* | **21 Nov 11** |
| 30 Jul–1 Aug | **10th International Energy Conversion Engineering Conference (IECEC)** | Atlanta, GA | *Jul/Aug 11* | **21 Nov 11** |
| 13–16 Aug | **AIAA Guidance, Navigation, and Control Conference**<br>**AIAA Atmospheric Flight Mechanics Conference**<br>**AIAA Modeling and Simulation Technologies Conference**<br>**AIAA/AAS Astrodynamics Specialist Conference** | Minneapolis, MN | *Jul/Aug 11* | **19 Jan 12** |
| 11–13 Sep | **AIAA SPACE 2012 Conference & Exposition** | Pasadena, CA | *Sep 11* | **26 Jan 12** |
| 11–13 Sep | **AIAA Complex Aerospace Systems Exchange Event** | Pasadena, CA | | |
| 17–19 Sep | **12th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference**<br>**14th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference** | Indianapolis, IN | *Oct 11* | **7 Feb 12** |
| 23–28 Sep† | **28th Congress of the International Council of the Aeronautical Sciences** | Brisbane, Australia<br>Contact: http://www.icas2012.com | | **15 Jul 11** |
| 24–27 Sep† | **30th AIAA International Communications Satellite Systems Conference (ICSSC) and**<br>**18th Ka and Broadband Communications, Navigation and Earth Observation Conference** | Ottawa, Ontario, Canada<br>Contact: Frank Gargione, frankgargione3@msn.com; www.kaconf.org | *Nov 11* | **31 Mar 12** |
| 24–28 Sep | **7th AIAA Biennial National Forum on Weapon System Effectiveness** | Ft. Walton Beach, FL | *Nov 11* | **15 Mar 12** |
| 1–5 Oct | **63rd International Astronautical Congress** | Naples, Italy (Contact: www. iafastro.org) | | |
| **2013** | | | | |
| 7–10 Jan | **51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition** | Dallas/Ft. Worth, TX | | |

To receive information on meetings listed above, write or call AIAA Customer Service, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344; 800.639.AIAA or 703.264.7500 (outside U.S.). Also accessible via Internet at www.aiaa.org/calendar.

†Meetings cosponsored by AIAA. Cosponsorship forms can be found at http://www.aiaa.org/content.cfm?pageid=292.

# AIAA **Courses** and **Training Program**

| DATE | COURSE | VENUE | LOCATION |
|---|---|---|---|
| **2012** | | | |
| 7–8 Jan | **CFD for Combustion Modeling** | ASM Meeting | Nashville, TN |
| 7–8 Jan | **Concepts in the Modern Design of Experiments** | ASM Meeting | Nashville, TN |
| 7–8 Jan | **Fluid Structure Interaction** | ASM Meeting | Nashville, TN |
| 7–8 Jan | **Sustainable (Green) Aviation** | ASM Meeting | Nashville, TN |
| 7–8 Jan | **Systems Requirements Engineering** | ASM Meeting | Nashville, TN |
| 7–8 Jan | **Modeling Flight Dynamics with Tensors** | ASM Meeting | Nashville, TN |
| 7–8 Jan | **Best Practices in Wind Tunnel Testing** | ASM Meeting | Nashville, TN |
| 22–23 Jan | **Missile Design and System Engineering** | StratTac Conference | Monterey, CA |

**Courses subject to change*

To receive information on courses listed above, write or call AIAA Customer Service, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344; 800.639.2422 or 703.264.7500 (outside the U.S.). Also accessible via the internet at www.aiaa.org/courses.

# From the **Corner** Office

## ATTRACTING A BROADER RANGE OF PROFESSIONALS TO AIAA

*Mike Griffin, AIAA President-Elect*

One of the things I enjoy most about our aerospace profession is the opportunity that we all have to attend conferences, symposiums, and other events where we can network with like-minded others—people who are in love with flight in all its forms, and with the technologies and systems that make it possible. I had the good fortune recently to attend just such a conference, one which featured papers and panel discussions on space systems architecture, international legal frameworks, intriguing new technologies, and thought-provoking discussions of national and international aerospace policy advocacy—an event where national heads of agencies gathered to meet with their counterparts, to participate in a panel discussion, or to deliver a keynote address. This conference was brimming over with energy, vitality, and—judging by the participants—youthful vigor. Unfortunately, the conference to which I refer was not an AIAA event; it was the International Astronautical Congress in Cape Town.

In thinking about this conference while on the way home, I realized that is has been a long time since I've attended an AIAA event with these characteristics. I think this observation is rooted in the same ground as another, namely that our Institute has as many members past the age of 60 as it does those who are under age 40. Now I and many of my dearest friends in the aerospace profession are in the former category, and I choose to believe that we can still contribute our share of vision, drive, and energy while also offering a healthy and needed reservoir of experience. But the demographics of our Institute are those of a dwindling organization, irrespective of the dedication possessed by its remaining members. Why is our membership declining? It is not because we are failing to attract the youngest engineers, the fresh-outs. We're doing well there. Where we are failing is in our ability to keep them; the demographic distribution of our membership is telling us that, in the years immediately after a newly graduated engineer joins the aerospace workforce, he or she leaves AIAA. *Why?* That is the question we need to ask and answer.

Unfortunately, the people who could tell us most directly why they are leaving are those who have already left, so those of us who are still part of the Institute must figure it out on our own. My present view is that we are losing, or never enrolling, most aerospace professionals because AIAA is, and is seen to be, representative of only a rather small minority of what aerospace professionals today are doing. Most of us work on large-scale aerospace systems, or play a role in advocating or managing the development or operation of these systems. Simply put, an enormous number of today's aerospace professionals are not involved in technical discipline work that conforms to the Technical Activities Committee structure that forms the core of our Institute. Most are not even aerospace engineers by training. They do not see a close relationship between what they do and what AIAA has historically been—the premier technical society of the aerospace professional.

While I would never, ever want AIAA to lose this distinction, I do not think we are well served as the future unfolds by hewing only to this line. We need to be distinct and distinguished across a broader range of the aerospace profession. Almost all lawyers belong to the American Bar Association. Almost all medical doctors belong to the American Medical Association. They do not practice the same specialties within law or medicine, nor do they necessarily agree on national policy issues germane to their professions. *But they belong.* When the same can be said of aerospace professionals and AIAA, we will know that we are again serving our profession the way we should. This is the topic upon which I most want to engage as president-elect and, soon, president of AIAA. I invite your thoughts as we go forward together; my e-mail address is michael@griffinspace.net.

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## How Far Can You See?

*At AIAA, we see aerospace transforming the future ... How Far Can You See?*

*What is your hope for the future of aerospace? What discoveries and breakthroughs are on the way and what difference will they make? Share your vision at* **www.aiaa.org/imagineit**.

I see a day in which the atmosphere is itself used as a propellant for commercial aircraft. Sonic waves can be used to lower forward atmospheric pressure while particles are supercharged through a diode chamber creating a pressure difference that would produce thrust. Airfoils can then be used not only for lift, but also to ride the pressure wave produced by the engine. The electricity required to create the sonic wave can be recycled energy from the engine itself as the spinning chamber around the diode is itself a generator. No fuel required, only a little spark.—**Nathaneal Hill, AIAA Student Member**


AIAA information booth at Air Expo '11 air show, Commemorating 100 Years of Naval Aviation, on 3 September at NAS Patuxent River in St. Mary's County, MD. Booth staffed by National Capital Section—Southern MD Chapter Officers Scott Fry and Monty Wright. Local AIAA Chapter activities and events highlighted.

## GPS RECOGNIZED BY INTERNATIONAL ASTRONAUTICAL FEDERATION

On 4 October 2011, the Global Positioning System (GPS) was recognized as the recipient of the International Astronautical Federation (IAF) 60th Anniversary Award. This one-time award recognized an outstanding achievement in the area of space applications for human benefit. The award was presented during a ceremony at the 62nd International Astronautical Congress, held 3–7 October 2011, in Cape Town, South Africa. AIAA, as an IAF member organization, nominated GPS for this award.

General William L. Shelton, Commander, United States Air Force Space Command, accepted the award on behalf of the GPS Program. The award was presented by IAF President Prof. Dr. Berndt Feuerbacher. As part of the ceremony, Dr. Bradford W. Parkinson, GPS Chief Architect and First Program Director and Professor (Emeritus) Aeronautics and Astronautics, Stanford University, gave a lecture about the history and benefits for humanity of the GPS program.

Other participants in the ceremony included Michael E. Shaw, Director, Navigation Systems Global Business Development, Lockheed Martin Space Systems, and AIAA Executive Director Bob Dickman. During the ceremony, Dickman said, "It was a distinct pleasure for AIAA to participate in preparing the nomination package for a number of reasons. First, because we believe so strongly that GPS indeed has been the space program that has had the greatest benefit for mankind since the founding of the IAF 60 years ago. Second, because so many of the pioneers in fielding the GPS system, and in sustaining and operating it, were and are members of AIAA. Third, because GPS has formed a basis for a Global Navigation Satellite System of Systems that is an excellent example of how a space system can serve uniquely national interests while at the same time adding to the usefulness and robustness of a much broader multinational capability that benefits all humankind."

Representing the GPS industry partners at the ceremony were Ken Torok, Vice President, Navigation & Communication Systems, Boeing; Joanne Maguire, Executive Vice President, Space Systems Company, Lockheed Martin; and Lynn Dugle, President, Intelligence and Information Systems, Raytheon. Boeing, with its legacy company Rockwell, is responsible for the Block I, II, IIA, and IIF satellites; Lockheed Martin is responsible for the Block IIR and GPS III satellites; and Raytheon is responsible for the common ground architecture.

AIAA Executive Director Bob Dickman spoke during the IAF award ceremony that recognized the GPS program. AIAA nominated GPS for this award.

To view the video of the ceremony, please visit **http://www.aiaa.org/content.cfm?pageid=928**.

AIAA published the seminal two-volume set *Global Positioning System: Theory and Applications* in 1996. This set explains the technology, performance, and applications of GPS. The books are the only of their kind to present the history of GPS development, the basic concepts and theory of GPS, and the recent developments and numerous applications of GPS. For more information about this publication, please visit **http://www.aiaa.org/content.cfm?pageid=360&id=568**.


The Global Positioning System received the IAF 60th Anniversary Award during the 62nd International Astronautical Congress. From left to right are Lynn Dugle, Dr. Bradford Parkinson, Prof. Dr. Berndt Feuerbacher, General William Shelton, Ken Torok, Joanne Maguire, and Bob Dickman.

### Important Announcement
### New Editor-in-Chief Sought for the *Journal of Aerospace Computing, Information, and Communication*

AIAA is seeking an outstanding candidate with an international reputation to assume the responsibilities of editor-in-chief of AIAA's *Journal of Aerospace Computing, Information, and Communication* (*JACIC*). The chosen candidate will assume the editorship at an exciting time as AIAA relaunches its electronic library with new features and functionality. Originally envisioned as an electronic-only, rapid-review journal, the new editor-in-chief will be able to take advantage of the new platform's capabilities to enhance *JACIC's* reputation and fulfill its mission.

The Editor-in-Chief is responsible for maintaining and enhancing the journal's quality and reputation as well as establishing a strategic vision for the journal. He or she receives manuscripts, assigns them to Associate Editors for review and evaluation, and monitors the performance of the Associate Editors to ensure that the manuscripts are processed in a fair and timely manner. The Editor-in-Chief works closely with AIAA Headquarters staff on both general procedures and the scheduling of specific issues. Detailed record keeping and prompt actions are required. The Editor-in-Chief is expected to provide his or her own clerical support, although this may be partially offset by a small expense allowance. AIAA provides all appropriate resources including a web-based manuscript-tracking system.

Interested candidates are invited to send letters of application describing their reasons for applying, summarizing their relevant experience and qualifications, and initial priorities for the journal; full résumés; and complete lists of published papers, to:

Rodger Williams
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Suite 500
Reston, VA 20191-4344
Fax: 703/264-7551
E-mail: rodgerw@aiaa.org

A minimum of two letters of recommendation also are required. The recommendations should be sent by the parties writing the letters directly to Mr. Williams at the above address, fax number, or e-mail. To receive full consideration, applications and all required materials must be received at AIAA Headquarters by **9 December 2011**, but applications will be accepted until the position is filled.

A selection committee appointed by the AIAA Vice President–Publications Michael B. Bragg will seek candidates and review all applications received. The search committee will recommend qualified candidates to the AIAA Vice President–Publications, who in turn will present a recommendation to the AIAA Board of Directors for approval. This is an open process, and the final selection will be made only on the basis of the applicants' merits. All candidates will be notified of the final decision.

## AIAA MEMBERS PARTICIPATE IN THE STEM CONFERENCE, HOSTED BY THE VA BEACH PUBLIC SCHOOL SYSTEM

The Virginia Beach City Public School System kicked off the school year in a big way, hosting a STEM Career Conference for 530 middle school students at Corporate Landing Middle School (CLMS) and Bayside Middle School. Staff from the Department of Curriculum and Instruction and CLMS collaborated with the National Institute of Aerospace (NIA), National Oceanographic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and AIAA in partnership with the 11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference to plan and implement the STEM event. The program was organized like a professional conference and was designed to help shape student expectations and attitudes about STEM studies while broadening their understanding of STEM career opportunities.

Members of the ATIO Outreach team and the local Hampton Roads AIAA section participated as presenters, conducting 40-minute sessions on various topics, including aircraft design, the principles of flight, exploring Antarctica, and careers in aerospace. The team also ate lunch with the students, giving the students an additional opportunity to ask questions of the presenters. Shelly Bremmeier and Sharon Bowers, members of the STEM K–12 Outreach Committee, coordinated the presentations with Dennis Carter, chair of the ATIO Outreach Commitee. Presenters included Mark Holly, Jeff Corbets, Cees Bil, Jason Merret, Cory Tallman, Hernando Jimenez, Zig Leszczynski, George A. Hazelrigg, Karen Berger, Keith Hoffler, Andy Hahn and Bird Taylor.

The ATIO Conference has had a long history of giving back to the community by conducting a K–12 event immediately after the conference with the assistance of the local AIAA section. Past programs have included airplane design workshops and competitions, workshops with Project Lead the Way, and tours of local aviation facilities to connect the aviation and local communities. Plans are underway for an outreach event in the Indianapolis, IN, community after the ATIO event next year. For more information, or to volunteer to participate, please contact Shelly Brimmeier at shelly.brimmeier@gulfstream.com.


Geoge Hazelrigg's "What's so cool about aviation?" presentation.


The "From Trash to Flight" session was led by Andrew Hahn.

The "Aircraft Design" session was led by Jeffrey Corbets.



Hernando Jimenez's "Exotic, Weird, and Fun Aircraft" presentation.

### LOCKHEED MARTIN EXECUTIVE JOINS EXCLUSIVE RANKS OF NATIONAL ACADEMY OF ENGINEERING

On 16 October, **Joanne M. Maguire**, executive vice president of Lockheed Martin Space Systems Company, was formally inducted into the National Academy of Engineering (NAE) in Washington, DC. She is an AIAA Fellow.

Election to the NAE is among the highest professional distinctions accorded to an engineer. Academy membership honors those who have made outstanding contributions to "engineering research, practice, or education, including, where appropriate, significant contributions to the engineering literature," and to the "pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education."

Maguire's citation recognizes her for "individual and team leadership of successful space programs." She becomes one of only 2,290 U.S members and 202 foreign associates elected to the NAE since its founding in 1964.

Maguire, also an officer of Lockheed Martin Corporation, has led Space Systems Company since 2006. Under her leadership the company provides a broad array of advanced-technology systems for national security, civil, and commercial customers. Chief products include human space flight systems; a full range of remote sensing, navigation, meteorological, and communications satellites; strategic and missile defense systems; space observatories and interplanetary spacecraft. Maguire serves on the board of directors for United Launch Alliance, a Lockheed Martin joint venture, and is on the board of Lockheed Martin UK, which oversees the Corporation's interests in Great Britain.

In 2010, Maguire became the first female to receive the prestigious International von Karman Wings Award presented by the California Institute of Technology for her visionary accomplishments in space, and she also was honored with UCLA's Alumni Achievement Award in 2010. She has been selected numerous times by *Fortune* magazine to its annual list of "50 Most Powerful Women in Business." In 2009, she received the Society of Women Engineers' Upward Mobility Award in recognition of her outstanding contributions in aerospace engineering and for pioneering work in technology and diversity management.

She earned a bachelor's degree in electrical engineering from Michigan State University and a master's degree in engineering from the University of California at Los Angeles (UCLA). Maguire also completed the executive program in management at UCLA's Anderson School of Management and the Harvard Program for Senior Executives in National and International Security. She received a presidential appointment as a full member/academician of the International Academy of Astronautics.

To submit articles to the *AIAA Bulletin*, contact your Section, Committee, Honors and Awards, Events, Precollege, or Student staff liaison. They will review and forward the information to the *AIAA Bulletin* Editor. See the AIAA Directory on page **B1** for contact information.

## EDUCATION ALLEY HOSTS 3,100 STUDENTS AT THE SPACE 2011 CONFERENCE AND EXPOSITION

Students learning how to use the solar telescopes.

Education Alley returned to the Long Beach Convention Center to host formal and informal educational groups over the three days of the SPACE 2011 Conference & Exposition. Education Alley, sponsored by Lockheed Martin, The Boeing Company, Northrop Grumman, Raytheon, The Aerospace Corporation, Wyle, Pratt & Whitney, and the AIAA Foundation, featured presentations from the STS-135 crew (the final crew to travel aboard the Space Shuttle), scientists from NASA Goddard Spaceflight Center, and an appearance by NASA spacesuit engineer Heather Paul from NASA Johnson Space Center.

Exhibitors created hand-on experiences in their booths to connect STEM education with opportunities in aerospace engineering and space to inspire students to study math and science. This year, telescopes dominated the programs. Jason Kalirai, Space Science Space Telescope Institute, explained the mission of the James Webb Telescope and the Solar Dynamics Observatory and solar telescopes were demonstrated by Romeo Durscher and Monica Bobra. Students and adults had many opportunities to learn about different ways to observe our solar system. During the lunch break, other presentations for the students were done by The Aerospace Corporation, Raytheon, the Air Force Research Laboratory (AFRL), and NOAA to demonstrate GPS, rocketry, cryrogenics and satellites, respectively.

Education Alley was attended by a large group from Farnsworth Aerospace Magnet School in Minneapolis, MN. This group, led by Principal Dr. Vincent, and taught by one of the 2011 AIAA Foundation Educator Achievement Award winners, Jill Wall, came to Southern California to visit NASA's Jet Propulsion Laboratory, the Challenger Learning Center for Space Education, and Education Alley. Other 2011 AIAA Foundation Educator Achievement Award winners Roger Kassebaum (The Milken School) and Chris Miko (DiVinci Academy) brought their students to be a part of Education Alley.

New this year was an afternoon event for about 700 local after-school programs, with an emphasis on Girl and Boy Scout groups. They were treated to presentations about the James Webb telescope and the STS-135 crew. Mission Specialist Sandy Magnus, a former Girl Scout, was a hit with scouts as she inspired them to live their dreams.

A Teachers Only event was also new this year. Teachers came and received resources from each of the exhibitors and heard about opportunities from NASA Distance Learning Network (DLN), the Space Science Telescope Institute, and AIAA. Teachers commented that they had no idea about many of the resources available to them at no charge. Many of them applied to become AIAA Educator Associates.

In addition to the corporate sponsors and the groups that provided presentations and materials, Education Alley was supported by Jane Hansen, Chair, Education Alley and a cadre of volunteers from Cal State University at Long Beach, as well as engineers from Los Angeles and Orange County AIAA sections. In addition, the AIAA Orange County Team America Rocketry Challenge (TARC), the Cal State Long Beach University, and San Diego State University Sounding Rocket programs shared their student-run projects with the attendees.

This program is one of many AIAA STEM K–12 Outreach Programs designed to inspire students to consider STEM careers. For information about this and other programs, please contact Lisa Bacon at lisab@aiaa.org.

STS-135 astronaut Sandy Magnus, a former Girl Scout herself, inspires Girl Scouts from the Long Beach, CA, area.

## CALL FOR NOMINATIONS

Recognize the achievements of your colleagues by nominating them for an award. Nominations are now being accepted for the following awards, and must be received at AIAA Headquarters no later than **1 February**. A nomination form can be downloaded from **www.aiaa.org**. AIAA members may also submit nominations online after logging in with their user name and password.

**Aerospace Guidance, Navigation, and Control Award**
Presented to recognize important contributions in the field of guidance, navigation, and control. (Presented even years)

**Aerospace Power Systems Award**
Presented for a significant contribution in the broad field of aerospace power systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and processing of aerospace power.

**Aircraft Design Award**
Presented to a design engineer or team for the conception, definition, or development of an original concept leading to a significant advancement in aircraft design or design technology.

**Daniel Guggenheim Medal**
The industry-renowned Daniel Guggenheim Medal was established in 1929 for the purpose of honoring persons who make notable achievements in the advancement of aeronautics. AIAA, ASME, SAE, and AHS sponsor the award.

**de Florez Award for Flight Simulation**
Named for the late Admiral Luis de Florez, the award honors an outstanding individual achievement in the application of flight simulation to aerospace training, research, and development.

**Energy Systems**
Presented for a significant contribution in the broad field of energy systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and conservation of energy.

**F. E. Newbold V/STOL Award**
Presented to recognize outstanding creative contributions to the advancement and realization of powered lift flight in one or more of the following areas: initiation, definition, and/or management of key V/STOL programs; development of enabling technologies including critical methodology; program engineering and design; and/or other relevant related activities or combinations thereof which have advanced the science of powered lift flight.

**George M. Low Space Transportation Award**
Honors the achievements in space transportation made by Dr. George M. Low, who played a leading role in planning and executing all of the Apollo missions, and originated the plans for the first manned lunar orbital flight, Apollo 8. (Presented even years)

**Haley Space Flight Award**
Presented for outstanding contributions by an astronaut or flight test personnel to the advancement of the art, science, or technology of astronautics. (Presented even years)

**Hap Arnold Award for Excellence in Aeronautical Program Management**
Presented presented to an individual for outstanding contributions in the management of a significant aeronautical or aeronautical related program or project.

**Hypersonic Systems and Technologies Award**
Presented to recognize sustained, outstanding contributions and achievements in the advancement of atmospheric, hypersonic flight and related technologies. (Presented every 18 months)

**J. Leland Atwood Award**
*Nominations due to AIAA by 1 January*
To recognize an aerospace engineering educator for outstanding contributions to the profession. AIAA and ASEE sponsor the award.

**Mechanics and Control of Flight Award**
Presented for an outstanding recent technical or scientific contribution by an individual in the mechanics, guidance, or control of flight in space or the atmosphere.

**Multidisciplinary Design Optimization Award**
Presented to an individual for outstanding contributions to the development and/or application of techniques of multidisciplinary design optimization in the context of aerospace engineering. (Presented even years)

**Otto C. Winzen Lifetime Achievement Award**
Presented for outstanding contributions and achievements in the advancement of free flight balloon systems or related technologies. (Presented odd years)

**Piper General Aviation Award**
Presented for outstanding contributions leading to the advancement of general aviation. (Presented even years)

**Space Automation and Robotics Award**
Presented for leadership and technical contributions by individuals and teams in the field of space automation and robotics. (Presented odd years)

**Space Science Award**
Presented to an individual for demonstrated leadership of innovative scientific investigations associated with space science missions. (Presented even years)

**Space Operations and Support Award**
Presented for outstanding efforts in overcoming space operations problems and assuring success, and recognizes those teams or individuals whose exceptional contributions were critical to an anomaly recovery, crew rescue, or space failure. (Presented odd years)

**Space Systems Award**
Presented to recognize outstanding achievements in the architecture, analysis, design, and implementation of space systems.

**von Braun Award for Excellence in Space Program Management**
Recognizes outstanding contributions in the management of a significant space or space-related program or project.

**William Littlewood Memorial Lecture**
The lecture perpetuates the memory of William Littlewood, who was renowned for the many significant contributions he made to the design of an operational requirements for civil transport aircraft. The topics for the lecture deals with a broad phase of civil air transportation considered of current interest and major importance. AIAA and SAE sponsor the lecture.

Answers to frequently asked questions or guidelines on submitting nominations for AIAA awards may be found at **http://www.aiaa.org/content.cfm?pageid=289**. For further information on AIAA's awards program, please contact Carol Stewart, Manager, AIAA Honors and Awards, at 703.264.7623 or at carols@aiaa.org.

## OBITUARIES

### *AIAA Senior Member Emeritus Smetana Died in May*

**Dr. Frederick O. Smetana** passed away on 27 May. He was 82 years old.

Dr. Smetana graduated from North Carolina State College in 1950 with a B.S. of Mechanical Engineering (Aero Option). He then worked for Douglas Aircraft Company in Santa Monica, CA, before returning to North Carolina State and earning a Master's Degree in June 1953. From July 1953–July 1955, he served as a flight test engineer in the U.S. Air Force at Edwards Air Force Base. From 1955–1961, he was a research scientist at the University of Southern California where he earned his Ph.D. in Engineering.

In 1961, Dr. Smetana joined the faculty of the North Carolina State University (NCSU) Mechanical and Aerospace Engineering Department, where he remained until his retirement in 1994. During his tenure, he wrote several textbooks and numerous technical articles in addition to his normal teaching duties. Following his retirement, he was Professor Emeritus and continued to write several additional textbooks, one of which has recently been translated in Chinese for use in universities in the Republic of China. Dr. Smetana had been a member of AIAA since 1948.

### *Former Goddard Center Director Townsend Dead at 87*

**Dr. John W. "Jack" Townsend, Jr.** died on 29 October. He was a rocket and satellite pioneer who was influential in creating the first meteorological, communications, and Earth viewing satellite systems.

Townsend earned his Bachelor of Arts, Masters of Arts, and an Honorary Doctor of Science in physics from Williams College in Boston. Starting in 1949, he served with the U.S. Naval Research Laboratory as a research physicist instrumenting V-2, Viking, and Aerobee sounding rockets for upper air research. When NASA was created in 1958, he transferred with his Branch and the Vanguard Project into the new agency, becoming Chief of its Space Sciences Division.

He helped form NASA's Goddard Space Flight Center, and came to the newly-formed space research Center in 1959 as its Assistant Director, Space Science and Satellite Applications. He was named Deputy Director of Goddard Space Flight Center in 1965 and continued to serve in that capacity until 1968.

In 1968, President Johnson appointed him the Deputy Administrator of the Environmental Science Services Agency. In 1970, President Nixon appointed him to the post of Associate Administrator of NOAA, where he remained until 1977. He was then President of Fairchild Industries Space Division, and held senior executive positions at Fairchild, including Executive Vice President from 1977 to 1987. After the *Challenger* accident, he returned to NASA at the request of then Administrator Fletcher and served essentially as general manager until the Space Shuttle safely returned to service. He retired in 1990.

Dr. Townsend chaired the National Research Council's Space Application Board and led many influential studies for the National Academies and other organizations, including the seminal, Low-Altitude Wind Shear and Its Hazard to Aviation. In 1975, he was elected to the National Academy of Engineering. He was a fellow of AIAA, the American Meteorological Society, and the American Association for the Advancement of Science.

# 15th Annual FAA Commercial Space Transportation Conference

15–16 February 2012
Walter E. Washington Convention Center
Washington, DC

## Synopsis

This annual two-day event brings together entrepreneurs, engineers, small businesses, academics, aerospace industry executives, government regulators, and legislators to share their insights about the exciting growth of the U.S. commercial space industry. This year's theme is "Commercial: The New Future of Space"—and that future is very bright, as big government space programs like the Space Shuttle make way for commercial launch service companies and entrepreneurs who are making their vision of lower-cost access to space a reality. The conference features dynamic high-level speakers, interactive panels on timely commercial space topics, and ample opportunities for informal networking.

## Why Attend?

The federal government's approach to space programs has changed significantly and will continue to evolve. New companies are entering the launch services market, while others are pioneering whole new markets such as space tourism or space solar power. Commercial companies are involved in everything from astronaut training to delivering cargo to the International Space Station. Meet the people who are making "Commercial" the new future of space.

## Who Should Attend?

### Launch Service Providers

- Understand commercial launch license requirements direct from responsible FAA staff
- Network with colleagues from all of the major industry innovators and providers
- Exchange ideas about requirements and solutions with government oversight officials from the FAA and NASA
- Learn about future commercial space activities from government and industry leaders

### Spacecraft Developers and Operators

- Get intimate insights into emerging launch systems and transportation concepts
- Interact with government and industry leaders about future commercial space activities
- Engage with leading launch service suppliers

### Spaceport Operators

- Understand the regulatory environment affecting spaceports directly from key FAA staff
- Network informally with colleagues from other spaceports and in the launch services community

### Suborbital Researchers

- Collaborate and coordinate research requirements with vehicle developers
- Understand the impact of suborbital designs on your R&D capabilities and integration specifications

### Government Regulators

- Discover the current status of all of the commercial vehicles receiving government support
- Interact with industry executives in a neutral forum to discuss viewpoints, issues, and optimum regulatory strategies

### Students and Early Career Professionals

- Meet the players making commercial space a reality
- Learn about emerging commercial space systems you might help develop

### Space Enthusiasts

- Gain first-hand insight on the current state of the industry
- Meet the players in a one-on-one environment

## What to Expect?

You'll meet the "movers and shakers" of the commercial space industry, and learn about the latest issues and developments that keep them awake at night. Since the conference is held in Washington, many attendees will schedule an extra day to meet with key legislators and staffers on Capitol Hill.

www.faa.gov/go/ast • www.aiaa.org/events/ast

Co-chaired by AIAA • Wednesday Luncheon Sponsored by Boeing

## Special Events and Networking Opportunities

***Continental Breakfasts***

Continental breakfasts for conference attendees will be available Wednesday and Thursday mornings at 0800 hrs.

***Luncheons***

Luncheons with featured speakers will be held Wednesday and Thursday, 15 and 16 February 2012, at the Walter E. Washington Convention Center. Times are indicated in the program. The cost of the luncheons is included in the registration fee where indicated. Additional tickets may be purchased upon registration or at the AIAA on-site registration desk.

***Networking Coffee Breaks***

Networking coffee breaks for conference attendees will be held Wednesday and Thursday in the morning and afternoon. Times are indicated in the program.

***Welcome Reception***

There will be a welcome reception on Wednesday, 15 February 2012, 1730–1900 hrs, at the Walter E. Washington Convention Center. The cost of the reception is included in the registration fee where indicated. Additional tickets may be purchased upon registration or at the AIAA on-site registration desk.

## Registration Information

AIAA is committed to sponsoring world-class conferences on current technical issues in a safe and secure environment. As such, all delegates will be required to provide proper identification prior to receiving a conference badge and associated materials. All delegates must provide a valid photo ID (driver's license or government/military I.D.) when they check in.

Participants are urged to register online at **www.aiaa.org/events/ast**. Registering in advance saves conference attendees up to $200. A check made payable to AIAA or credit card information must be included with your registration form. A PDF registration form is also available on the AIAA Web site. Print, complete, and mail or fax the form with payment to AIAA. Address information is provided.

All early-bird registration forms must be received by **16 January 2012**, and standard registration forms will be accepted until **14 February 2012**. Preregistrants may pick up their materials at the advance registration desk at the conference. All those not registered by **14 February 2012** may do so at the AIAA on-site registration desk.

Cancellations must be in writing and received no later than **30 January 2012**. There is a $100 cancellation fee. Registrants who cancel beyond this date or fail to attend the conference will forfeit the entire fee. For questions, please contact Sandra Turner, AIAA conference registrar, at 703.264.7508 or sandrat@aiaa.org.

Registration fees are as follows:

| | **Early Bird** | **Standard** | **On-Site** |
|---|---|---|---|
| | By 16 Jan | 17 Jan–14 Feb | On-Site |
| *Option 1: Full Conference* | | | |
| Conference | $735 | $835 | $935 |
| Member Discount/ Government | $580 | $680 | $780 |

Includes sessions, Wednesday and Thursday luncheons, and Wednesday welcome reception.

| *Option 2: Full-Time Undergraduate Student* | | | |
|---|---|---|---|
| Conference | $50 | $60 | $70 |
| Member Discount/ Government | $20 | $30 | $40 |

Includes sessions only.

| *Option 3: Full-Time Undergraduate Student with Tickets* | | | |
|---|---|---|---|
| Conference | $249 | $259 | $269 |
| Member Discount/ Government | $219 | $229 | $239 |

Includes sessions, Wednesday and Thursday luncheons, and Wednesday welcome reception.

| *Option 4: Full-Time Graduate or Ph.D. Student* | | | |
|---|---|---|---|
| Conference | $90 | $100 | $110 |
| Member Discount/ Government | $60 | $70 | $80 |

Includes sessions only.

| *Option 5: Full-Time Graduate or Ph.D. Student with Tickets* | | | |
|---|---|---|---|
| Conference | $289 | $299 | $309 |
| Member Discount/ Government | $259 | $269 | $279 |

Includes sessions, Wednesday and Thursday luncheons, and Wednesday welcome reception.

| *Option 6: Full-Time AIAA Retired Member* | | | |
|---|---|---|---|
| Conference | N/A | N/A | N/A |
| Member Discount/ Government | $40 | $50 | $60 |

Includes sessions, Wednesday and Thursday luncheons, and Wednesday welcome reception.

| *Option 7: Discounted Group Rate* | | | |
|---|---|---|---|
| | $522 per person | $522 per person | N/A |

10% discount off AIAA member rate for 10 or more persons from the same organization who register and pay at the same time with a single form of payment. Includes sessions and all catered events. A complete typed list of registrants, along with completed individual registration forms and a single payment, must be received by the preregistration deadline of **14 February 2012**.

***Extra Tickets***

| | |
|---|---|
| Wednesday Luncheon | $57 |
| Wednesday Welcome Reception | $85 |
| Thursday Luncheon | $57 |

## Registration and Information Center

The onsite Registration and Information Center hours will be:

| | |
|---|---|
| Wednesday, 15 February 2012 | 0800–1700 hrs |
| Thursday, 16 February 2012 | 0800–1700 hrs |

## Parking and Metro Information

Public parking is available around the Walter E. Washington Convention Center. Fees vary per facility. Please check the convention center Web site, www.dcconvention.com, for information. The Mt Vernon Sq/7th St-Convention Center Metro station (yellow and green lines) is the nearest station to the convention center.

## Certificate of Attendance

Certificates of Attendance are available for attendees who request documentation at the conference itself. Please request your copy at the on-site registration desk. AIAA offers this service to better serve the needs of the professional community. Claims of hours or applicability toward professional education requirements are the responsibility of the participant.

## Sponsorship Opportunities

A variety of sponsorship opportunities are available to achieve your overall branding objectives. For information regarding sponsorship, please contact: Cecilia Capece, AIAA Sponsorship Program Manager, 703.264.7570, E-mail: ceciliac@aiaa.org

## Preliminary Program

### Technical Program

The conference features a dynamic mix of technical information and commercial space business and policy issues. Subjects range from risk assessment and space weather to the latest developments in legislation and government funding opportunities.

### Networking

Attendees will appreciate the many opportunities the conference provides for expanding their personal networks of contacts, including:

- Daily Luncheons
- Daily Networking Coffee Breaks
- Wednesday Evening Welcome Reception

### Keynote Speakers (Invited and Confirmed)

- The Honorable Randy Babbitt, Administrator, Federal Aviation Administration (invited)
- The Honorable Ray LaHood, Secretary of Transportation (invited)
- The Honorable Gregory L. Schulte, Deputy Assistant Secretary of Defense for Space Policy (invited)
- General William L. Shelton, USAF, Commander, U.S. Space Command (invited)
- Owen Garriott, NASA astronaut (confirmed)
- Others to be announced soon!

## Panel Descriptions

**Launch Ranges of the Future**
Moderator: Pam Underwood, FAA/AST
Panelists: Col Rob Uemura, Chief, Current Space Operations (AF/A3Z-SO) (invited); Scott Henderson, Director of Mission Assurance, SpaceX (invited); Les Kovacs, Orbital Sciences (invited); John Kelley, Launch Services Program Executive, NASA (invited); Michael Moses, Vice President of Operations, Virgin Galactic (invited); Chris Anderson, Director, Spaceport America (invited)

With the retirement of the Space Shuttle, the commercial space transportation industry is at a critical point of opportunity. Commercial industry is moving to undertake missions traditionally launched by the government, and to spark the curiosity and excitement of the public to boost the space tourism industry. Launch ranges in the future will need to account for the needs of this changing industry. The panel will explore the needs of this changing industry and current launch range capabilities from the perspective of government and of industry stakeholders.

**Crew and Cargo to ISS**
Moderator: Robert Dickman, Executive Director, AIAA
Panelists: TBD

Hear an update on the latest developments in the critical Commercial Crew Development (CCDev) program, and plans for expanding commercial launch services to the International Space Station to include manned spaceflight.

**Understanding the Space Environment: What the Launch Operator Should Know about Space Weather**
Moderator: Karen Shelton-Mur, FAA/AST
Panelists: TBD

Space weather—the charged particles and radiation from the sun and other sources—affects us all, even on the ground. The effects are of even greater concern for space travelers, spacecraft, and launch vehicles.

**New Minds, New Ideas: Student Presentations**
Moderator: Jay Naphas, FAA/AST
Panelists: TBD

The college years have always been a time to take risks. Bold new directions and ideas can be explored in college, more so than at any other time in life. Young thinkers are a major source of innovation. Here we take a look at college research to see their view of what the next big thing might be.

**Minority Space Entrepreneurship**
Moderator: Kelvin Coleman, FAA/AST
Co-Moderator: Ken Harvey, President and CEO, JAKA Consulting Group
Panelists: Congressman Chaka Fattah (D- PA) (invited); Joseph Fuller, President and CEO, Futron Corporation; Allen Herbert, President and CEO, Phezu Space LLC; Jayfus Doswell, President and CEO, JUXTOPIA Group (invited)

Minority space entrepreneurs discuss their companies' space-related endeavors and their contributions to the overall success of U.S. commercial space transportation. Panel members will provide their views and insights on how minority entrepreneurs in the United States can leverage their skills and capabilities to become a greater part of what is expected to become a trillion dollar industry.

**Integration of Public and On-Board Safety**
Moderator, Paul Wilde, FAA/AST
Panelists: TBD

Industry and government representatives will discuss safety assessments and risk-acceptability decisions made during the design, certification, and operation of launch and reentry vehicles for human spaceflight. The focus will be on how past experiences can help facilitate a robust commercial human spaceflight industry.

**Training for Safety**
Moderator: Barbara Lunde, FAA/AST
Panelists: Doug Conley, Sea Launch (invited); Linda Tyree, United Launch Alliance (invited); Neil Milburn, Armadillo Aerospace (invited); Robert Millman, Blue Origin (invited)

How can training of commercial launch crews and support personnel best enhance mission safety? The panel will address initial training, continuing training, and proficiency exercises, as well as the desirability of various certifications.

**Legislative Trends in Commercial Space**
Moderator: Greg Rasnake, FAA/AST
Panelists: TBD

Lawmakers play a key role in the commercial space enterprise. Government programs and budgetary issues are major market determiners, and liability legislation, taxes, and export controls all affect the bottom line of the space business. Panelists will discuss the latest legislative developments and trends.

**Solar Power Satellites: The 'Next Big Thing' in Commercial Space?**

Moderator: Nick Demidovich, FAA/AST

Panelists: John C. Mankins, President, Artemis Innovation Management Solutions, LLC (confirmed)

The idea of huge orbital solar collectors beaming power back to Earth has been around for decades. But until now, this has not been economically practical. New technological developments may soon change that equation, opening up an enormous new market for commercial space.

**Spaceport States Leadership Panel**

Moderator: John Logsdon, George Washington University

Panelists: The Honorable Sean Parnell, Governor of Alaska (invited); The Honorable Rick Scott, Governor of Florida (invited); The Honorable Susana Martinez, Governor of New Mexico (invited); The Honorable Mary Fallin, Governor of Oklahoma (invited); The Honorable Rick Perry, Governor of Texas (invited); The Honorable Robert F. McDonnell, Governor of Virginia (invited)

The number of commercial launch sites is steadily growing, as forward-thinking states promote the development of these facilities. This panel will feature the governors of "spaceport states" (or their designated representatives), describing the initiatives they have undertaken, and the anticipated results.

**The Tipping Point**

Moderator: Ken Davidian, FAA/AST

Panelists: TBD

"The tipping point" commonly refers to the moment at which an idea or product "goes viral" and suddenly experiences explosive growth. The panel will take a close look at where commercial space is today, and how it might facilitate its own "tipping point."

## Highlights from the 2011 Event

- "Straight from the shoulder" remarks by FAA Administrator Randy Babbitt and NASA Administrator Charles Bolden.
- Joe Engle's riveting and entertaining description of flying the X-15 to the edge of space, from his perspective as a test pilot and Shuttle astronaut.
- Spaceport managers assembled to share their philosophies on a common set of spaceport standards.
- Robert Bigelow moderated a panel of launch company representatives examining the future of orbital launch vehicles.

For complete conference information, visit **www.aiaa.org/events/ast**.

# Upcoming AIAA Professional Development Courses

**7–8 January 2012**
**The following Continuing Education classes are being held at the 50th AIAA Aerospace Sciences Meeting in Nashville, Tennessee. Registration includes course and course notes; conference, Wednesday awards luncheon, Wednesday evening reception, Thursday evening reception, and single-user access to the online conference proceedings.**

**ASM COURSE AND CONFERENCE REGISTRATION FEES**

To register, go to **www.aiaa.org/events/asm.**

| | Early Bird by 12 Dec 2011 | Standard (13 Dec–5 Jan) | Onsite (6–8 Jan 2012) |
|---|---|---|---|
| AIAA Member | $1265 | $1365 | $1465 |
| Nonmember | $1343 | $1493 | $1643 |

**CFD for Combustion Modeling** (Instructors: Heinz Pitsch, RWTH Aachen University, Aachen Germany and Suresh Menon, School of Aerospace Engineering, Atlanta, GA)
The objective of the course is to provide the interested combustion engineer or researcher with the fundamentals of combustion modeling to assess a combustion problem and to decide on the adequate models to be used in numerical simulations. The course is designed also to provide the knowledge to implement certain models into CFD codes. The course starts with fundamentals of combustion chemistry and includes a hands-on introduction to a 0D/1D combustion code. This is followed by a brief introduction to statistical models and turbulence modeling. A comparative overview of the most commonly used combustion models will be given next. Implementation issues and application examples will be discussed. Special topics include combustion instabilities, combustion in aircraft engines, augmenters, and high-speed combustion.

**Concepts in the Modern Design of Experiments** (Instructor: Richard DeLoach, NASA, Hampton, VA)
Aerospace researchers with considerable subject-matter expertise who have had relatively little formal training in the design of experiments are often unaware that research quality and productivity can be substantially improved through the specific design of an experiment. Reductions in cycle time by factors of two or more, with quality improvements of that same order, have occurred when the fundamental precepts of experiment design covered in this course have been applied in real-world aerospace research. Examples drawn from specific studies will quantitatively illustrate resource savings, quality improvements, and enhanced insights that well-designed experiments have delivered at NASA Langley. Computer software CDs included with the course (Design Expert) will be demonstrated.

**Fluid Structure Interaction** (Instructor: Rainald Löhner, George Mason University, Fairfax, VA)
The course will give an overview of the phenomena that govern fluid-structure interaction, as well as numerical methods that can be used to predict them. A wide range of phenomena, ranging from aeroelasticity to weapon fragmentation, will be covered.

**Sustainable (Green) Aviation** (Instructor: Ramesh K. Agarwal, Washington University, St. Louis, MI)
The titles “Sustainable Aviation” or “Green Aviation” are recently being used with increasing frequency to address the technological and socioeconomic issues facing the aviation industry to meet the environmental challenges of the twenty-first century. Air travel continues to experience the fastest growth among all modes of transportation, especially because of the tremendous increase in demand in major developing nations and emerging economies of Asia and Africa. It is forecasted that by 2025, 27,200 new airplanes worth $2.7 trillion would be needed. As a result of threefold increase in air travel by 2025, it is estimated that the total CO2 emission due to commercial aviation may reach between 1.2 billion tonnes to 1.5 billion tonnes annually by 2025 from its current level of 670 million tonnes. The amount of nitrogen oxides around airports, generated by aircraft engines, may rise from 2.5 million tonnes in 2000 to 6.1 million tonnes by 2025. The number of people who may be seriously affected by aircraft noise may rise from 24 million in 2000 to 30.5 million by 2025. Therefore, there is urgency to address the problems of emissions and noise abatement through technological innovations in design and operations of the commercial aircraft. The environmental issues such as noise, emissions, and fuel consumption, for both airplane and airport operations, have become important for energy and environmental sustainability.

This short course provides an overview of issues related to air transportation and its impact on environment, followed by topics dealing with emissions and noise mitigation by technological solutions including new aircraft and engine designs/technologies, alternative fuels and materials, and operational improvements/changes. The ground infrastructure for sustainable aviation, including the concept of “Sustainable Green Airport Design” is also covered. The integrated Aircraft/Engine/Operations analysis tools for Environmental Performance Studies of various aircrafts are also presented. Finally, the topics related to climate policy for civil aviation, including the economic analysis models with environmental, are covered.

**Systems Requirements Engineering** (Instructor: John C Hsu, CA State University, The University of CA at Irvine, Queens University and The Boeing Company, Cypress, CA)
Requirements analysis and specification development are the most important contribution at the onset of a program/project. It will set a corrective direction to guide the program/project preventing the later-on redesign and rework. This course will help you familiarize with an effective method for defining a set of requirements of a system. The focus is on the initial problem space definition, defining user needs, concept of operations, systems, segment, subsystem requirements, and architecture. Gain an understanding of the following requirements engineering activities: elicitation of requirements, system requirements analysis, requirements integration, interface requirements and control, functional analysis and architecture, requirements management, and verification and validation of requirements. Learn about the principles and characteristics of organizing a well-written requirements and specifications.

## Modeling Flight Dynamics with Tensors (Instructor: Peter H Zipfel, University of Florida, Shalimar, FL)

Establishing a new trend in flight dynamics, this two-day course introduces you to the modeling of flight dynamics with tensors. Instead of using the classical "vector mechanics" technique, the kinematics and dynamics of aerospace vehicles are formulated by Cartesian tensors that are invariant under time-dependent coordinate transformations.

This course builds on your general understanding of flight mechanics, but requires no prior knowledge of tensors. It introduces Cartesian tensors, reviews coordinate systems, formulates tensorial kinematics, and applies Newton's and Euler's laws to build the general six-degrees-of-freedom equations of motion. For stability and control applications, the perturbation equations are derived with their linear and nonlinear aerodynamic derivatives. After taking the course, you will have an appreciation of the powerful new "tensor flight dynamics," and you should be able to model the dynamics of your own aerospace vehicle.

## Best Practices in Wind Tunnel Testing (Instructors: David M. Cahill, Aerospace Testing Alliance, Arnold AFB, TN; Mark Melanson, Lockheed Martin Aeronautics, Fort Worth, TX; and E. Allen Arrington, NASA Glenn Research Center, Cleveland, OH)

This course provides an overview of important concepts that are used in many wind tunnel test projects. The course is based largely on AIAA standards documents that focus on ground testing concepts. In particular, the course will address project management aspects of executing a testing project, the use and calibration of strain gage balances, the use of measurement uncertainty in ground testing, and the calibration of wind tunnels.

**22–23 January 2012**

**The following Continuing Education class is being held at the AIAA Strategic and Tactical Missile Systems Conference and AIAA Missile Sciences Conference in Monterey, California. Registration includes course and course notes; sessions (with approved security clearance form); Tuesday, Wednesday, and Thursday luncheons; and Tuesday and Wednesday receptions.**

**STRAT TAC COURSE AND CONFERENCE REGISTRATION FEES**

To register, go to **www.aiaa.org/events/strattac** or **www.aiaa.org/events/missilesciences**

| | *Early Bird by 19 Dec 2011* | *Standard (20 Dec–21 Jan)* | *Onsite* |
|---|---|---|---|
| AIAA Member | $1188 | $1338 | $1488 |
| Nonmember | $1265 | $1415 | $1565 |

***Note**: A Security Clearance Certification Form is also required for this event (by **19 December 2011**). The Security Clearance Certification Form is separate from conference registration. Submitting a Security Clearance Certification Form does not register you for the conference. You must also register with AIAA.*

## Missile Design and System Engineering (Instructor: Gene Fleeman, International Lecturer, Lilburn, GA)

This short course provides the fundamentals of missile design, development, and system engineering. A system-level, integrated method is provided for missile configuration design and analysis. It addresses the broad range of alternatives in satisfying missile performance, cost, and risk requirements. Methods are generally simple closed-form analytical expressions that are physics-based, to provide insight into the primary driving parameters. Configuration-sizing examples are presented for rocket, turbojet, and ramjet-powered missiles. Systems engineering considerations include launch platform integration constraints. Typical values of missile parameters and the characteristics of current operational missiles are discussed as well as the enabling subsystems and technologies for missiles. Sixty-six videos illustrate missile development activities and performance. Attendees will vote on the relative emphasis of types of targets, types of launch platforms, technical topics, and roundtable discussion.

## Publications

# New and Forthcoming Titles

### Boundary Layer Analysis, Second Edition
*Joseph A. Schetz and Rodney D. Bowersox*
AIAA Education Series
2011, 760 pages, Hardback
ISBN: 978-1-60086-823-8
AIAA Member Price: $84.95
List Price: $114.95

### Introduction to Flight Testing and Applied Aerodynamics
*Barnes W. McCormick*
AIAA Education Series
2011, 150 pages, Hardback
ISBN: 978-1-60086-827-6
AIAA Member Price: $49.95
List Price: $64.95

### Space Operations: Exploration, Scientific Utilization, and Technology Development
*Craig A. Cruzen, Johanna M. Gunn, and Patrice J. Amadieu*
Progress in Astronautics and Aeronautics Series, 236
2011, 672 pages, Hardback
ISBN: 978-1-60086-817-7
AIAA Member Price: $89.95
List Price: $119.95

### Spacecraft Charging
*Shu T. Lai*
Progress in Astronautics and Aeronautics Series, 237
2011, 208 pages, Hardback
ISBN: 978-1-60086-836-8
AIAA Member Price: $64.95
List Price: $84.95

### Exergy Analysis and Design Optimization for Aerospace Vehicles and Systems
*Jose Camberos and David Moorhouse*
Progress in Astronautics and Aeronautics Series, 238
2011, 600 pages, Hardback
ISBN: 978-1-60086-839-9
AIAA Member Price: $89.95
List Price: $119.95

### Engineering Computations and Modeling in MATLAB/Simulink
*Oleg Yakimenko*
AIAA Education Series
2011, 800 pages, Hardback
ISBN: 978-1-60086-781-1
AIAA Member Price: $79.95
List Price: $104.95

### Introduction to Theoretical Aerodynamics and Hydrodynamics
*William Sears*
AIAA Education Series
2011, 150 pages, Hardback
ISBN: 978-1-60086-773-6
AIAA Member Price: $54.95
List Price: $69.95

### Eleven Seconds into the Unknown: A History of the Hyper-X Program
*Curtis Peebles*
Library of Flight
2011, 330 pages, Paperback
ISBN: 978-1-60086-776-7
AIAA Member Price: $29.95
List Price: $39.95

### Basic Helicopter Aerodynamics, Third Edition
*John M. Seddon and Simon Newman*
AIAA Education Series
Published by John Wiley & Sons, 2011, 3rd Edition, 264 pages, Hardback
ISBN: 9-781-60086-861-0
AIAA Member Price: $49.95
List Price: $74.95

### Gas Turbine Propulsion Systems
*Bernie MacIsaac and Roy Langton*
AIAA Education Series
Published by John Wiley & Sons, 2011, 368 pages, Hardback
ISBN: 9-781-60086-846-7
AIAA Member Price: $84.95
List Price: $119.95

### Encyclopedia of Aerospace Engineering: 9-Volume Set
*Richard Blockley and Wei Shyy, University of Michigan*
2010, 5500 pages, Hardback
ISBN-13: 978-0-470-75440-5
AIAA Member Price: $3,375
List Price: $3,750

***View complete descriptions and order 24 hours a day at www.aiaa.org/new***

# Standard Information for all AIAA Conferences

This is general conference information, except as noted in the individual conference preliminary program information to address exceptions.

### Photo ID Needed at Registration

All registrants must provide a valid photo ID (driver's license or passport) when they check in. For student registration, valid student ID is also required.

### Conference Proceedings

This year's conference proceedings will be available in an online format only. The cost is included in the registration fee where indicated. If you register in advance for the online papers, you will be provided with instructions on how to access the conference technical papers. For those registering on-site, you will be provided with instructions at registration.

### Young Professional Guide for Gaining Management Support

Young professionals have the unique opportunity to meet and learn from some of the most important people in the business by attending conferences and participating in AIAA activities. A detailed online guide, published by the AIAA Young Professional Committee, is available to help you gain support and financial backing from your company. The guide explains the benefits of participation, offers recommendations and provides an example letter for seeking management support and funding, and shows you how to get the most out of your participation. The online guide can be found on the AIAA Web site, **www.aiaa.org/YPGuide**.

### Journal Publication

Authors of appropriate papers are encouraged to submit them for possible publication in one of the Institute's archival journals: *AIAA Journal*; *Journal of Aircraft*; *Journal of Guidance, Control, and Dynamics*; *Journal of Propulsion and Power*; *Journal of Spacecraft and Rockets*; *Journal of Thermophysics and Heat Transfer*; or *Journal of Aerospace Computing, Information, and Communication*. You may now submit your paper online at **http://mc.manuscriptcentral.com/aiaa**.

### Speakers' Briefing

Authors who are presenting papers, session chairs, and co-chairs will meet for a short briefing at 0700 hrs on the mornings of the conference. Continental breakfast will be provided. Please plan to attend only on the day of your session(s). Location will be in final program.

### Speakers' Practice

A speaker practice room will be available for speakers wishing to practice their presentations. A sign-up sheet will be posted on the door for half-hour increments.

### Timing of Presentations

Each paper will be allotted 30 minutes (including introduction and question-and-answer period) except where noted.

### Committee Meetings

Meeting room locations for AIAA committees will be posted on the message board and will be available upon request in the registration area.

### Audiovisual

Each session room will be preset with the following: one LCD projector, one screen, and one microphone (if needed). A 1/2" VHS VCR and monitor, an overhead projector, and/or a 35-mm slide projector will only be provided if requested by presenters on their abstract submittal forms. AIAA does not provide computers or technicians to connect LCD projectors to the laptops. Should presenters wish to use the LCD projectors, it is their responsibility to bring or arrange for a computer on their own. Please note that AIAA does not provide security in the session rooms and recommends that items of value, including computers, not be left unattended. Any additional audiovisual requirements, or equipment not requested by the date provided in the preliminary conference information, will be at cost to the presenter.

### Employment Opportunities

AIAA is assisting members who are searching for employment by providing a bulletin board at the technical meetings. This bulletin board is solely for "open position" and "available for employment" postings. Employers are encouraged to have personnel who are attending an AIAA technical conference bring "open position" job postings. Individual unemployed members may post "available for employment" notices. AIAA reserves the right to remove inappropriate notices, and cannot assume responsibility for notices forwarded to AIAA Headquarters. AIAA members can post and browse resumes and job listings, and access other online employment resources, by visiting the AIAA Career Center at http://careercenter.aiaa.org.

### Messages and Information

Messages will be recorded and posted on a bulletin board in the registration area. It is not possible to page conferees. A telephone number will be provided in the final program.

### Membership

Professionals registering at the nonmember rate will receive a one-year AIAA membership. Students who are not members may apply their registration fee toward their first year's student member dues.

### Nondiscriminatory Practices

The AIAA accepts registrations irrespective of race, creed, sex, color, physical handicap, and national or ethnic origin.

### Smoking Policy

Smoking is not permitted in the technical sessions.

### Restrictions

Videotaping or audio recording of sessions or technical exhibits as well as the unauthorized sale of AIAA-copyrighted material is prohibited.

### International Traffic in Arms Regulations (ITAR)

AIAA speakers and attendees are reminded that some topics discussed in the conference could be controlled by the International Traffic in Arms Regulations (ITAR). U.S. Nationals (U.S. Citizens and Permanent Residents) are responsible for ensuring that technical data they present in open sessions to non-U.S. Nationals in attendance or in conference proceedings are not export restricted by the ITAR. U.S. Nationals are likewise responsible for ensuring that they do not discuss ITAR export-restricted information with non-U.S. Nationals in attendance.